Background Paper:

CHINESE RENEWABLES STATUS REPORT

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REN21 Renewable Energy Policy Network for the 21st Century

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Lead Authors

Junfeng Li and Lingjuan Ma (Chinese Renewable Energy Industry Association)

Contributors

Overview: Shannon Wang (REN21 Secretariat / UNEP)

Wind technology: Wuming Yu (Xinjiang Wind Energy Liability Co., Ltd)

Solar PV: Fang Lv (Beijing Jikedian Renewable Energy Development Centre)

Solar Hot Water: Jinliang Yang (Beijing North Solar Technology Ltd. Co)

Biomass Power Generation: Shipin Qin (National Development and Reform Commission, Energy Research Institute)

Biogas: Xin Liu (Energy and Environmental Development Research Centre)

Liquid Bioful: Mengjie Wang (Chinese Academy of Agricultural Engineering)

Small Hydropower: Juandong Tong (International Centre on Small Hydro Power)

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1 Geographic, Economic and Demographic Overview

1.1 Geography

China is located in East Asia and on the western shores of the Pacific Ocean. It has a land area of approx. 9.6 million sq km. The Northern part of the Chinese territory starts from the centre of Heilongjiang River, north of Mohe (latitude 53°30′ north) and ends in the south at Zengmu Reef, the southernmost tip of Nansha Islands (latitude 4° north), spanning over 49 degrees; it starts in the east from the confluence of the Heilongjiang and Wusuli rivers (longitude 135°05′ east) and ends in the west at the Pamirs (longitude 73°40′ east), spanning over 60 degrees. Both south-north and east-west spans are over 5,000 km. It has land borders 22,800 km long, and 18,000 km coast line with 4.73 million sq km seas.

1.2 Economy

China has developed as planned and on a large scale, as a result China is among the countries with the greatest economic potential in the world. The livelihood of Chinese people has been improved and reached a well-off level in general. National Five Year Plans (FYPs) started since 1953 have been accomplished with impressive achievements and paved a sound way for the national economy growth. The reform and opening-up initiated since 1979 has strongly driven China’s economy that is kept steady even after 2000.

Elementary socialist market economy mechanism has been established in China, and market has played a better role in resource allocation. The macroeconomic control system is gradually improved. The national economy consists of state-owned and private sectors developing together, with the state-owned sector holding the majority. The growing model is gradually shifting from extensive to intensive style. According to the scheduled plan, China will achieve a well-structured socialist market economy system which is expected to be mature by 2020.

According to the report of the National Bureau of Statistics of China (NBS) issued on October 27, 2008, the share of China’s economy in the global portfolio has increased from 1.8 percent in 1978 to 6 percent in 2007. It indicated that from 1978 to 2007 the actual average growth rate of GDP was annually 9.8 percent, which is not only obviously higher than 6.1 percent in 1953-1978 but also significantly higher than the global average of 3 percent over the same period. Comparing with 8.5 percent of Korea and 9.2 percent of Japan in the take-off stage of economy, China has done as well as them. The gaps between China and the major developed countries are narrowing in terms of economy. It ranks the 4th largest countries in the world by GDP, following USA, Japan and Germany. The 2007 GDP of China was USD3,280.1 billion, accounting for 23.7 percent of USA, 74.9 percent of Japan and 99.5 percent of Germany, representing an increase of 17.2 percent, 59.7 percent and 78.9 percent over 1978 respectively. The per capita GDP in China increased from USD190 in 1978 to USD2,360 in 2007. The country is classified in the lower middle category by the World Bank by per capita income.

1.3 Demography

China has the largest population in the world. NBS says in the report issued on February 26, 2009, as of the end of 2008, the total population was 1.308 billion, representing an increase of 6.73 million over the year before. The new born population in 2008 was 16.06 million, with a birth rate of 12.13‰; and the number of death is 9.35 million, with a death rate of 7.06‰. The rate of natural growth is 5.08‰.

As of the end of 2008, the 60-year-old or above population reached 158.89 million, accounting for 12 percent. The report that is issued by NBS on November 3, 2008 says that As of the end of 2007 Chinese population accounts for 20.1 percent of the world's total, comparing with 22.2 percent in 1980. The decreasing is driven by the family planning policy since 1979. China is experiencing steady growth of population, civilization improvement and increasing labor force. On average, every 5 adults only need to feed 2 children or old people. China has a population structure at a golden period.

1.4 Climate Change, Development and Energy Security

Many observations of the last 100 years show that the earth's climate is now experiencing significant change characterized by global warming. And the trend of climate change in China is generally consistent with that of global climate change. To address climate change and promote sustainable development, China has carried out various policies and measures, such as economic restructuring, energy efficiency improvement, development and utilization of hydropower and other renewable energy, ecological restoration and protection, as well family planning, which has contributed significantly to the mitigation of climate change.

The Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) has clearly indicated that most of the global warming observed over the past 50 years is likely induced by the increase in concentrations of greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), due to human activities. In the context of global warming, climate in China has experienced noticeable changes over the past 100 years as well. The major observed evidence of climate change in China includes the following:

--Temperature. Annual average air temperature has increased by 0.5-0.8℃ during the past 100 years, which is slightly greater than the average global temperature rise. Most of the temperature rise is observed over the last 50 years.

The regional distribution of the temperature changes shows that the warming trend is more significant in western, eastern and northern China than in the south of the Yangtze River. The seasonal distribution of the temperature changes shows that the most significant temperature increase occurred in winter, and 20 consecutive warm winters are observed nationwide from 1986 to 2005.

--Precipitation. In the past 100 years, there is no obvious trend of change in annual precipitation in China, but there exists considerable variation among regions. The annual precipitation decreased gradually since 1950s with an average rate of 2.9 mm/decade, although it increased slightly during the period of 1991-2000. The regional distribution of precipitation shows that the decrease in annual precipitation is significant in most of northern China, eastern part of the northwest, and northeastern China, averaging 20-40 mm/decade, with decrease in northern China being most severe. The precipitation significantly increased in southern China and southwestern China, averaging 20-60 mm/decade.

--Extreme climate/weather events. The frequency and intensity of extreme climate/weather events throughout China have experienced obvious changes during the last 50 years. Drought in northern and northeastern China, and flood in the middle and lower reaches of the Yangtze River and southeastern China have become more severe. The annual precipitation in most years since 1990 has been larger than normal, with the precipitation pattern being a dipole, corresponding to frequent disasters in the North and flood in the South.

--Sea level. The rate of sea level rise along China's coasts during the past 50 years is 2.5 mm/yr, slightly higher than the global average.

--Glaciers. The mountain glaciers in China have retreated, and the trend is accelerating. The trend of climate warming in China will further intensify in the future.

The projections by Chinese scientists indicate that:

--The nationwide annual mean air temperature will increase by 1.3-2.1℃ in 2030 and by 2.3-3.3℃ in 2050 comparing with that in 2000. The warming magnitude will increase from south to north in China, particularly in northwestern and northeastern China where significant temperature rise is projected. It is estimated that by 2030, the annual temperature will likely increase by 1.9-2.3℃ in northwestern China, 1.6-2.0℃ in southwestern China, and 2.2-2.6℃ in the Qinghai-Tibetan Plateau.

--Precipitation in China will possibly increase during the next 50 years, with a projected nationwide increase of 2-3 percent by 2020 and 5-7 percent by 2050. The most significant increase might be experienced in southeastern coastal regions.

--The possibility of more frequent occurrence of extreme weather/climate events will increase in China. It will have great impact on the socio-economic development and people's life.

--The arid area in China will probably become larger and the risk of desertification might increase.

--The sea level along the coasts in China will continue to rise.

--The glaciers in the Qinghai-Tibetan Plateau and the Tianshan Mountains could retreat at an accelerated rate, and some smaller glaciers will disappear.

GHG emission in China

According to the Initial National Communication on Climate Change of the People's Republic of China, China's total GHG emission in 1994 was 4.06 billion tons of CO2 equivalent (tce) (3,650 Mt of net emission), including 3,070 Mt of CO_2, 730 Mt CO_2 equivalent of CH4 and 260 million tce of N_2O. China's experts estimate that China's total GHG emission in 2004 was approx. 6,100 tce (5,600 Mt, net), including 5,050 Mt CO_2, 720 million tce of CH_4 and 330 million tce of N_2O. From 1994-2004, the annual average growth rate of GHG emission was approx. 4 percent, and the share of CO_2 in total GHG emission increased from 76 percent to 83 percent.

China's historical GHG emission is very low and per capita emission has been below the world average. According to the study carried out by the World Resource Institute (WRI), China's CO_2 emission from fossil fuel combustion is 79 Mt in 1950, accounting for only 1.13 percent of the world total at that time, while the cumulative emission accounts for only 9.33 percent during the period of 1950-2002. The cumulative CO_2 emission per capita was 61.7 tons over the same period, ranking the 92nd in the world. Statistics from the International Energy Agency (IEA) indicates that per capita CO_2 emission from fossil fuel combustion was 3.65 tons in 2004 in China, accounting for only 87 percent of the world average and 33 percent of that of countries in Organization for Economic Co-operation and Development (OECD).

China took lead in developing the *China's Agenda of 21st Century - White Paper on China's Population, Environment and Development*, after the United Nations Conference on Environment and Development in 1992, and adopted a series of policies and measures, taking into account its own situation and making positive contribution to the mitigation of climate change.

Measures to tackle the climate change in China

-- Restructuring the economy, promoting technology advancement and improving energy efficiency.

Since late 1980s, Chinese Government has paid more attention to the change of the economic growth pattern and the restructuring of economy, and integrated reduction of energy and other resources consumption, promotion of clean production, and prevention and control of industrial pollution into its national industrial policies. The industrial structure has been significantly improved through the implementation of a series of industrial policies to accelerate the development of the tertiary industry and to restructure the secondary industry. The breakdown of GDP across the primary, secondary and tertiary industries in 1990 was 26.9:41.3:31.8, while in 2005 it was 12.6:47.5:39.9. The share of primary industry declined continuously, and the tertiary grew greatly, especially in sectors such as telecommunication, tourism and finance. The secondary industry has slightly grown in the overall share, but its internal composition has significantly changed, and the proportion of high value-added products has increased due to the rapid development in machinery, information technology and electronic sectors. Such change has brought significant energy conservation benefits. During the period of 1991-2005, China achieved an annual GDP growth rate of 10.2 percent with an annual growth rate of 5.6 percent in energy consumption and an elasticity of energy consumption of approx. 0.55.

Since 1980s, Chinese Government has adopted a principle of "equal treatment to development and conservation with immediate emphasis on the latter", making energy conservation as a matter of strategic importance in energy policy. Energy conservation is effectively promoted through the implementation of the *Energy Conservation Law of the People's Republic of China (ECL)* and relevant regulations, the development of specific energy conservation plans, the adoption and implementation of technological, economic, fiscal and administrative policies in favor of energy conservation, the development and application of energy efficiency standards and labeling, the encouragement of RDD&D and diffusion of energy-saving technologies, the importing and absorbing of advanced energy-saving technologies, the creation and employment of new energy conservation mechanisms, and the promotion of key energy conservation projects as well. From 1990 to 2005, China's energy intensity (energy consumption per RMB million GDP at price in 2000) went down from 268tce to 143tce, representing an average year-over-year falling rate of 4.1 percent. The unit energy consumption of energy-intensive products in industry declined strikingly. In 2004, comparing with 1990, for generators with capacity of 6MW or above, the unit energy consumption for thermal power supply decreased from 427gce/kWh to 376gce/kWh. The comparable energy consumption for 1 ton of steel in key businesses decreased from 997kgce to 702kgce. The comprehensive energy consumption per ton of cement in large-and-medium-sized businesses decreased from 201kgce to 157kgce. During the period of 1991-2005, with economy restructuring and energy efficiency improvement, 800 Mtce of energy are saved, equivalent to a CO_2 emission reduction of 1.8 billion tons, based on a factor of 2.277 t CO_2/tce for China in 1994.

-- Optimizing energy mix by developing low-carbon and renewable energy

Under national policy guidance and with financial support, the share of high-grade and clean energy is improved by strengthening the development and utilization of hydropower, nuclear energy, oil, gas and coal-bed methane (CBM), and by supporting the development and utilization of new and renewable energy including biomass, solar, geothermal and wind power in rural, remote and other suitable areas.

2 Overview of the Energy Sector

China produced 2.5 Btce energy in 2008, 3.98 times up from 1978 level, with an average annual growth rate of 4.7 percent. China is ranked as the second largest energy production country just behind the United States, and the energy self-supply rate has reached 90 percent. According to NBS, the production of crude coal in China was 2.716 Bt in 2007, ranked the first in the world, increased by 3.33 times from 1978. By the end of 2008, the installed capacity of power generation reached 792 GW, increased by 12.8 times from 1978, and the annual growth rate is over 9 percent. The power generation in 2008 reached 3,433.4 TWh, 12.58 times over that of 1978 with an annual growth rate of 9 percent. At the same time, the development of renewable energy has been well advanced. The share of hydropower, nuclear and wind in the overall power generation has increased from 3.1 percent in 1978 to 9 percent in 2007. For the past years, the share of installed capacity of renewable has been growing rapidly, from 14 percent in 2005 to 17 percent in 2008.

The 17th National Congress of the Communist Party of China, held in October 2007, set the goals of accelerating the transformation of the development pattern and quadrupling the per-capita GDP of the year 2000 by 2020 by optimizing the economic structure and improving economic returns while reducing energy consumption and protecting the environment. The outline of *the 11th Five-Year Plan for National Economic and Social Development of the People's Republic of China* projects that the per-unit GDP energy consumption by 2010 will decrease by 20 percent compared to 2005, and the total amount of major pollutants discharged will go down by 10 percent.

To realize the country's economic and social development goals, the 11^{th} FYP (2006-2010) for the energy industry has put forth the following goals. By 2010, energy supply shall meet the demand of national economic and social development. Other goals include significant progress in energy saving, highly improved energy efficiency, further optimized energy structure, technological advancement, greater economic benefits and market competitiveness, as well as improved energy-related macro-control, market supervision, legislation and emergency system compatible with the socialist market economy. The result will be that energy production can be favorable for economy, society and environment.

In 2006, the unit GDP energy consumption in China was 1.206 tce/ RMB10, 000, down by 1.33 percent from 2005. There has been an annual decrease of 3.66 percent in 2007 and 4.21 percent in 2008. It is largely due to the closing down of many small coal-fired power plants. With appropriate combination of policies and measures, China has closed 16.69 GW capacity of coal-fired power plants in 2008, with the annual goal completed. In the past three years, the accumulated shut down capacity has reached 34.2 GW, accounting for 68.4 percent of the total shutdown target within the 11^{th} FYP. By replacing the small coal-fired power plants with the large ones, it has saved 43 Mt of coal, reduced 73,000 t SO_2 and 69 Mt CO_2 emissions. In 2008, more than 1,000 outdated coal mines were closed, with a capacity of 40 Mt.

3 Wind power

3.1 Overview

People's Republic of China Renewable Energy Law (the ReLaw) has been considered and approved by the tenth session of 10^{th} National People’s Congress (NPC) Standing Committee on February 28, 2005, which has decided the implementation of *the ReLaw* from January 1, 2006. A series of matching detailed rules and regulations were issued after *the ReLaw* has been issued.

China’s wind power industry has developed at an explosive rate during the past four years (2005-2008). The total wind power installation in China has reached 1,260 MW in 2005, 2,597 MW in 2006, 6,040 MW in 2007, and 12,152 MW in 2008. The annual growth rate is over 100 percent, averagely 113 percent. The wind turbine manufacturing is experiencing rapid development, with lots of manufacturers emerged within a short period of time. There are 70 wind turbine manufacturers under planning and expect to have a capacity of over 30,000 MW per year by 2010. Wind power industrial chain keeps extending with a group of service providers coming into being, such as project development, installation, operation and management, technical services within quality warranty period, equipment repair and professional cleaning. It is expected that within the next few years, China’s wind power industry will continue to maintain the relatively high growth rate. China is leader in installed capacity globally, equipment manufacturing scale and professional services, bringing a bright future for the expansion of Chinese wind industry.

3.2 Analysis on Resources and Economic Potential

3.2.1 China's Wind Resources

Different results have been generated by different organizations on the Chinese wind resources potential both technologically and economically. According to the second and third survey on national wind power resources, China's onshore 10-meter-high wind resources that can be developed theoretically are 3,226 GW and 4,350 GW, and technically available resources are, 253 GW and 297 GW respectively. The research results from United Nations Environment Program (UNEP) in 2005 show that China's onshore 50-meter-high wind resources that can be technically developed are 1,400 GW. The evaluation results from China National Climate Center in 2006 showed that China's onshore 10-meter-high wind resources that can be technically developed are 2,458 GW without considering the case of Qinghai-Tibet Plateau (the above data refer to *China Wind Report 2008*, P17). As Chinese Academy of Engineering (CAE), China's onshore wind power resources should range from 300 GW to 1,400 GW, both of which are much higher than the data from national survey. It is suggested by some experts that the wind resources at the specific site can be calculated as the number of wind turbines that can be installed under current wind power engineering technical and economic conditions within a certain area of land. Accordingly, the third national wind power resources survey shows that China's onshore wind farm with the density exceeding 150W/sq m is 200,000 sq km. Based on common wind farm layout for plain terrain (4D×8D), the installed capacity could be 2,000 GW. Taking account of the geographic impact such as the non-plain terrain, the feasible installation capacity should be 1,500 GW.

As previously estimated, China's offshore wind power resource is about 750 GW. Calculation has been made based on the 16,000-31,000 sq km of sea area that is suitable for wind turbines installation, which gives an achievable offshore wind resource at approx. 100-200 GW.

It's noticed that both onshore and offshore wind resource potential requires further study to gain a better understanding on its explosive rate. But confidence is given for achieving 1,500-2,000 GW of installation capacity with existing wind resources. Therefore within the next few decades, wind resources will not be a restricted factor to the development of China's wind industry.

3.2.2 Economic Factors Influencing Development of Wind Industry

In 2008, China's new wind power installation was 6,246 MW that enabled an accumulative capacity of 12,152 MW. It's projected that by 2010 an accumulative capacity of 20 GW will be achieved, 2.2% of the total electricity installation planned by the State Grid by that year (estimated to be 900 GW). By 2020 the total wind installation will reach 100 GW by the current plan, 8.3% percent of the total power installation capacity (1,200 GW as planned). In the next decade, the share of wind power in power grid installed capacity will still remind small, a longer timeframe is foreseen for wind to play a significant role as an alternative energy. It's also debated that due to the small portion in the total electricity supply there won't be severe influence on the grid as well as the power economy in the near future. However, wind energy can play a positive role in energy saving and emission reduction, environmental pollution easing, and energy portfolio improvement.

It is a rather complex to give an accurate evaluation on the impact of world's financial crisis on Chinese wind energy industry. At least by the end of the first quarter of 2009, there is no obvious negative influence has been spotted. It can be seen from the bright side of the financial crisis, lots of countries including the United States, pay more attention to renewable energy development, and take it as one of the most important strategic solutions to overcome the crisis and to prevent a recession. Power industry takes a certain proportion in the economic revitalization investment with RMB4 trillion (RMB3 trillion for renewable energy, equivalent to USD440 billion) funded by Chinese government. In the following years, the investment for power installation will be increased, including power grid investment, which is essential for wind power generated electricity to go on to the grid. Some key equipment manufacturers have been listed as one of the ten industries in economic revitalization plan. As statistics show the average per kW investment is RMB10,277 (USD1,511) for wind farm in 2008, and investment per million kW is about RMB10 billion (USD1.46 billion) for wind farm construction, which will be actively pulling GDP.

3.3 Development Status and Goals

In 2008, wind farm construction in China keeps expanding rapidly, hitting new record. The newly-added installation capacity in 2008 was 6,246 MW (5,132 turbines), and the total installed capacity was 12,152 MW (approx. 11601 turbines), twice as many as that of the last year. Thus, China's rank has been raised to the fourth place in the world, only following U.S. (25,170 MW), Germany (23,903 MW), and Spain (16,740 MW). At provincial level, Inner Mongolia is a pioneer in terms of installation with the newly-added capacity of 2,172 MW and the total installed capacity of 3,939 MW, followed by Liaoning, Hebei and Jilin provinces. The three provinces have an installed capacity of 1,250 MW, 1,111 MW and 1,069 MW respectively. And the installed capacity in some other areas exceeded 500 MW, such as Heilongjiang, Jiangsu, Gansu, Xinjiang and Shandong.

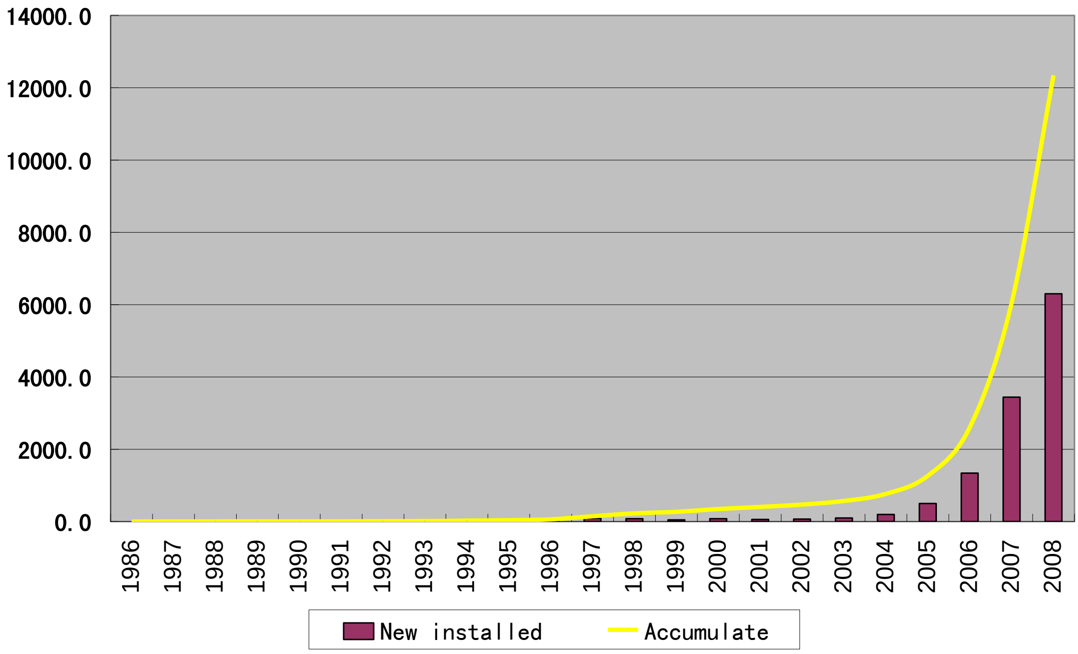
In the past few years a new feature has appeared in the wind industry: some regions with relatively scarce wind resources, such as Henan, Chongqing, Jiangxi, Hubei, Hunan and Yunnan have already started to construct and develop wind farms. On one hand, the wind power installation has been expanded greatly at the geographical scale. On the other hand, it has raised new technical and economic challenges.

There were 199 wind farm projects were approved in 2008 with a total capacity of 11,670MW. By the end of 2008, 1,840MW capacity has been installed and 9,830MW is currently under construction, which means 2009 will continue the high installation growth rate as the previous years. Five concessional programmes have been approved by the end of 2008, with a total of 49 projects and 8,800MW installation capacity. There were 18 projects at the stage of under construction or construction completed, with an operational capacity of 1,570MW, which accounted 13 percent of overall national wind installation capacity. A large number of the rest of the operational projects were approved at either provincial or regional level.

In 2009, the National Energy Administration puts forward a Wind Development Principal on constructing large wind bases connected to grids. A target is to build a tremendous wind power base at 10 GW level. Currently, the construction of the wind base in Yumen of Gansu Province has been kicked off. The complementary transmission project of 750 KV starts construction. The planning for wind bases in East Inner-Mongolia (30 GW), West Inner-Mongolia (20 GW), and Xinjiang Hami (20 GW), North Hebei (10 GW) and Jiangsu Coastline (10 GW) is undergoing.

Besides, wind power equipment manufacturing industry also has achieved great accomplishment in the past years. Before 2004 there were less than five such manufacturers in China, whose market shares in total were less than 15 percent. By the end of 2007, there were 40 manufacturers included domestic ones, foreign-funded businesses and joint ventures. Furthermore they have carried out intensive R&D of wind turbine technology. In 2007, the newly-added installation capacity was 3,443 MW, among which the share of domestic businesses accounted for 56 percent. As of the end of 2008, the number of domestic wind turbine manufacturers increased to 70, the newly-added installed capacity was 6,246 MW, among which the share of both domestic and joint venture businesses increased to 75.4 percent. By 2010, the 15 assembly manufacturers will have capacity of 20,325 MW; plus other manufacturers, development zones under planning and wind power industrial parks, it is estimated that the total capacity will exceed 30,000 MW, greatly beyond market demand.

Figure 1 The development trends of China's wind power installation (MW)



3.4 Policies, Standards and Local Regulations

Benefiting from the favorable policies, China wind power industry has gone through rapid development in the past years. The publication of *the ReLaw* and a series of detailed implementing regulations are the ultimate momentum for the industrial development. *The ReLaw* has solved some key issues that have restricted the scale up of wind power industry for a long time.

3.4.1 Grid Connection Policy for Wind Power

The law regulates that all grid companies should purchase all the electricity generated from renewable energy sources and provide grid connection service. To put the rules into effect, the State Electricity Regulation Commission（SERC）released *the Regulatory Measures on Off-take Purchase of Electricity from Renewable Energy Sources by Grid Companies* in its 25th order in 2007. For coal fire power generator, the grid company will select the coal fire power plants through the feed-in-tariff bidding process. Before the issuance of the regulator measure for renewable energy purchase by grid company, the related policies have clarified that wind power does not participate in feed-in tariff bidding, and regulated that wind power has the priority in electricity dispatching to power grid. Therefore, the obstacles for grid connection of wind power have been weeded out by these policies.

3.4.2 Wind Power Price Difference Allocation Policy

The *Interim Management Measures for Renewable Power Tariff and Cost Allocation* has been issued by NDRC in 2006, and the *Interim Measures on Renewable Power Surcharge Collection and Allocation* has been issued by NDRC in 2007. With the above two issued policies, the rules in the *ReLaw* that renewable energy price difference shall be obtained from the provincial electricity sales revenue and adjusted by the State in a unified way, have became effective. The historical fact was that the faster the development of wind power in remote and poor regions, the higher the electricity tariff and the heavier the financial burden. This problem has been addressed by the measures that have activated development of wind power in provinces and cities.

In order to ensure the financing of the price difference through the allocation fund, NDRC notified in 2006 that since June 30, the power grids of each province in China shall surcharge of additional RMB0.001 (USD$1.5x10^{-4}$) per kW for renewable energy, this would enable a collection of RMB3 billion (USD439 million) in 2007. In 2008, the surcharge has been adjusted to RMB0.002 (USD$3x10^{-4}$), with the collected income exceeding RMB6 billion (USD878 million). There were 48 projects in China have received the compensation of the premium tariff amounted to RMB260 million (USD38.1 million) in 2006, of which Xinjiang, Jilin, Inner Mongolia and Tibet obtained RMB91.71 million (USD13.43 million) from Jiangsu, Zhejiang, Shandong and Henan. From January to September 2007, there were 110 projects received subsidies amounted to RMB714 million (USD105 million). From October 2007 to June 2008, 148 projects in total obtained this compensation amounted to RMB1.954 billion (USD286 million). Among them, 102 projects were wind power projects, with the total installed capacity of 5,000 MW and 5.92 billion kWh electricity connected to the grid. They have received the subsidy of RMB1.382 billion (USD202 million) (*Power Station Information*, P2, Issue 12, 2008).

3.4.3 Feed-in Tariff Pricing Mechanism of Wind Power

In the *Interim Management Measures for Renewable Power Tariff and Cost Allocation* issued by NDRC, it is provided that two modes are adopted for the pricing of renewable power. One is that the price is set up by government and the other mode is guided by government. The guided price is the successful bidding price fixed by tender and especially for concession projects. The successful bidding price for five concession projects is between RMB0.382/kWh and RMB0.551/kWh. The price decided by government is mainly for the projects that are approved by provinces and less than 50 MW. The approved power price is between RMB0.51/kWh and RMB0.68/kWh, different from that of concession projects. It is worth paying more attention to the fact that in evaluating conditions of the fifth batch of concession projects, the condition of winning the highest score for feed-in tariff in bidding was changed from the lowest quoted price to the one that is most close to the average quoted price. The wining price for the fifth batch of projects is RMB0.468-0.551/kWh, from which it can be seen that the feed-in tariff becomes increasingly reasonable. According to the statistics, the average price (tax included) is RMB0.5975/kWh for approved wind farm projects in 2008. As a whole, forming a fixed mechanism of feed-in tariff and returning to reasonable price are the necessary conditions and ultimately assurance for wind industry development.

3.4.4 Discussion on RPS Requirement

The Medium- and Long-term Plan for Renewable Energy has been issued by NDRC in August, 2007, in which it is the first time to put forward that in areas covered by large power grids, non-hydro renewable power generation’s share of total power generation will reach 1 percent by 2010 and over 3 percent by 2020. It is required that the power plants with equity installed capacity of over 5 GW shall have an equity installed capacity of non-hydro renewable energy accounting for 3 percent of their total capacity by 2010, and over 8 percent by 2020. At current stage, only wind power has scaled up in all non-hydro renewable energy. It is estimated that if the total installed capacity of power grid reaching 0.9 billion kW by 2010, the 3 percent wind power will be 27,000 MW. The plan has provided momentum and specific targets for the major power generation groups to develop wind power. Although the quota system has not been carried out, the plan has been an important factor driving the rapid development for the last years.

3.4.5 Driving Force of Clean Development Mechanism (CDM)

In October 2005, NDRC, Ministry of Science and Technology（MOST）, Ministry of Foreign Affairs（MFA） and Ministry of Finance（MOF）jointly issued *the Measures on the Operation and Management of CDM Projects*, which promotes the development of China CDM projects. The newly-built wind projects meeting the CDM conditions are submitted for approval. As of January 12th, 2009, there are 367 projects in China that have been successfully registered with CDM Executive Board. Among them, there are 95 wind power projects, accounting for 25 percent of the total. The total installed capacity of registered wind projects is 5,589.65 MW, accounting for approx. 50 percent of the completed wind projects. Based on 2,000 hours of power generation on average, 5.6 Mt coal is saved and 10.22 Mt CO_2 emissions is reduced annually. As for the CDM projects, their feed-in tariff can get a subsidy of RMB0.07-0.14 /kWh subject to sales price within the given period. It is favorable for China’s wind industry since the feed-in tariff of wind projects is still relatively low in China, making most of wind projects profitable. The subsidy is popular among wind farm owners.

3.4.6 Fiscal Subsidy

The national fund, mainly through subsidy policy, strongly supports the R&D of wind power technology and wind turbine. In addition to this, both MOST and NDRC are giving their strong supports to the research and innovation of domestic wind turbine and its parts through various national technological plans and special R&D funds for renewable energy respectively. Since the *Interim Management Measures on Special Fund for Wind Power Generation Equipment Industrialization* was issued by MOF in August 2008, many incentives have been extended to encourage the R&D of new wind power equipment. The *Notice on Adjustment of Import Tax Policies for High-Power Wind Turbine and Its Key Parts and Raw Materials* has been issued by MOF, which rules that import tax shall be collected for wind turbines of 2.5 MW or below and import duty and value-added tax (VAT) shall be collected for the key parts before rebate, supporting the localized production of wind equipment. These policies and measures played an active role in long-term healthy development of China’s wind industry. The No. 224 File issued by NDRC in February 2009 requires the further planning of wind power development, doing a good job in supporting wind power grid construction, ensuring the grid connection of all the electricity from approved wind projects, strictly implementing price policies and clarifying tariff in a timely manner and formulating the grid connection management measures based on requirements of wind power. New requirements have been put forth for solving the existing problems in wind power development.

3.4.7 Local Policy Support

In addition to the national unified policies, some places and departments have also issued preferential policies to encourage wind industry development according to their actual situation. Wind power feed-in tariff has been increased from RMB0.53/kWh to RMB0.689/kWh in Guangdong Province, changing the cold picture of wind power investment over the past years. A large number of wind projects have been submitted for approval. *Wind Power Equipment Development Program* has been issued by Jiangsu Province. It points out that by 2020, Jiangsu will basically form a wind turbine manufacturing capacity of 8,000 MW and a sales revenue of RMB100 billion. The *Guide for Development of Wind Power Equipment in National Defense Industry* issued by the Commission of Science, Technology and Industry for National Defense (COSTIND) says that it is planned to build 2-3 domestically leading wind turbine manufacturing businesses by 2020, with an annual manufacturing capacity of 2,000 turbines. Gansu Province has proposed and actively promoted the construction of a wind base just like the Three Gorges in Hexi Corridor, and attracted manufacturing plants to Gansu by using the opportunity that China has approved the construction of the 10 GW wind power base, with the aim of optimizing the industrial structure. Hebei Development and Reform Commission requires further planning of wind power development, better construction of 1 GW wind power base and power grids and improvement of Hebei wind power industry, which have played a practical role in promoting China's wind power industry.

3.5 Investment and Industry Trend

From 2007 to 2008, China had state-owned businesses as wind farm investors, such as the five major power generation groups, Shenhua Group, China Energy Conservation Investment Corporation, and Guangdong Nuclear Power Group. Among them, China Longyuan Electric Power Group Corp. is a typical one. Longyuan Group is the first one breaking the milestones of 1000 MW and 2000 MW in installed capacity of wind power. As of the end of 2008, the total installed capacity of Longyuan was 2,800 MW, among which the 1,375 MW was newly added in 2008. Following Longyuan, Datang and Huaneng had installed capacity of 1,073 MW and 933 MW in 2008 respectively. As planned by Longyuan, it is expected to have its wind power installed capacity exceed 5,000 MW by 2010, and 20,000 MW by 2020, with which it will remain No.1 in China (*Wind Power Generation*, P1, Issue 2, 2008). Some other power generation groups and the large state-owned businesses which are new into this field for the past years, such as Three Gorges Group and Guohua Energy Investment Corporation, and also some local state-owned investors, such as Hebei Construction and Investment Group, all put forward the ambitious development plans with the installed capacity goals of more than 10,000 MW. What can be estimated is that within the next few years China wind farm investment will still mainly be made by large SOEs. In view of the great strength of these large SOEs as well as their enthusiasm for wind power industry, it is expected that in the near future, investment funds will not be a constraint for development of wind power industry.

For the past years, some of public and private businesses with potential and strength have showed their great interest in wind farm construction, and have done a variety of preliminary works for investment. However, since there are many difficulties, they cannot make actually big progress, thus having a small market share. The scattered power stations invested by individuals or families can be connected to the grid nearby, and also can make full use of land resources, ease the pressure on grid caused by large wind power access to grid and comply with the concept of distributed energy system. There is no doubt that the stations are feasible and can bring about benefits both theoretically and technically. According to the current management system, there will be a series of difficulties in the approval procedures, grid connection, the relationship between the sale and purchase of electricity. The existing management system is not favorable for the development, so it is still difficult to put them in practice. Overall, the situation that China wind power investment is mainly made by SOEs will not change in the near future.

In general, it is the same situation for wind manufacturing. Among so many turbine assembly and parts manufacturing businesses, state-owned capital takes the majority. The difference is that some listed companies, such as Goldwind, Dongfang Electricity, Nanjing Gaozai Gear, are leading the industry, while lots of private businesses, such as Zhengjiang Huayi, Shenyang Huachuang, Guangdong Mingyang and Huiquan of Inner Mongolia, have actively engaged in manufacturing turbine and its parts, starting their long journey in the new industry,

3.6 Rural Electrification

The promotion of rural electrification by wind power is mainly shown in the promotion and popularization of off-grid turbines, providing electricity for poor families in uncovered areas.

In 2007, China produced 54,800 small-and medium-sized off-grid wind turbines, with the year-over-year growth of 9.6 percent, the total capacity of 35 MW, and the output value of RMB18 million. The 19 models include 100 W, 150 W, 10 KW and 100 KW. The production in 2008 was 78,411 turbines with approx. 73 MW capacity. From 1983 to the end of 2008, China produced 508,712 small off-grid wind turbines in total. It is estimated that there are approx. 0.19 million small wind turbines still being used, with the installed capacity of approx. 57 MW and the annual power generation of 83.22 GWh. China is a global leader in annual output, total output, production capacity and export of small wind turbines. There are about 10 colleges, universities and research institutes, 36 turbine production companies, and 28 parts production companies engaging in the related business. There are several companies with larger annual output, such as Jiangsu Shenzhou Wind Power, Hunan Zhongke Hengyuan Technology, Guangzhou Hongying Energy Technology, Ningbo Wind King, Beijing Yuandong Boli, Long Xinbo and Tianli Machinery of Inner Mongolia. The off-grid turbine provides electricity for poor families in uncovered areas. Its applications extend to broadcast and communication relay stations, street lights, garden lights, fishing boats and public facilities.

China off-grid wind turbines have been increasingly popular in foreign countries. In 2007, China has exported more than 19,000 off-grid wind turbines, with the total capacity of 21 MW, and in 2008 39,387 turbines. There are 46 countries and regions to be exported to, such as Korea, India, Indonesia, Japan, the Philippines, Pakistan, Argentina, Australia, Britain, and the United States (Some of the data come from the *Report on Development of China Off-gird Wind Power Industry* by Mr Li Defu).

3.7 R&D

Chinese government attaches great importance to sci-tech innovation of wind power industry. The key projects in the field have been supported by the 863 Plan, the 973 Plan, science and technology supporting plan initiated by MOST, and the renewable energy special fund on R&D from NDRC. Lots of technologies have been listed in related plans and special programs, such as the technologies of MW-level, direct drive and permanent magnetic, full power and inverse wind turbine and its key parts, and MW-level, double-feed, variable speed and constant frequency (VSCF) wind turbine and its major parts; industrialization of domestic wind turbines; and off-shore wind power technology. The investment has been made by Hunan, Shanghai and Zhejiang to support the R&D of wind power technology.

With the State support, a batch of wind turbines and parts manufacturing businesses started to exert their main role in technology innovation in various forms, and strived to have their own intellectual property rights (IPR), with some achievements having been made. Goldwind has purchased Vensys based in Germany, which was a design partner of Goldwind in new MW-level turbine design. Thus Goldwind is now firmly controlling IPRs of dominant products and the technology development rights for new products. Sinovel and Dongfang Electricity have digested the technologies of imported turbines for improvement and innovation. Some businesses are developing 3-5 MW turbines and the special turbines for off-shore wind power. Besides, some parts manufacturing businesses, such as Baoding Huiteng, Nanjing Gaozai Gear and Yongji Electric Equipment Co., have developed and manufactured products based on requirements of turbine businesses. Insisting on innovation with improved independent design capability, they have launched new products in succession. Some of manufacturing companies also provide parts of turbine for manufacturers in foreign countries. All in all, China is lagging behind in the core technology and independent innovation capability of wind equipment manufacturing and does not have a team of experts who have a full understanding of core design technologies of wind turbine. There is a lack of basic wind generation theory, assistant tools and research results for independent innovation. There is no state-level R&D platform for wind power generation technology. The fundamental theory research on wind power has not been carried out. The efforts in this regards have to be enhanced.

3.8 Local Case Study: Development of Wind Power Industry in Inner Mongolia

Inner Mongolia has gone through tremendous growth in the past years in wind power installed capacity and becomes the model region in China. Comparing with the other areas, Inner Mongolia firstly reached the milestone of 1 GW installed capacity in 2007, with 1,736 turbines (1,585 MW) as of the end of the year. In 2008, the newly-added installed capacity of Inner Mongolia was 2,354 MW, with the total capacity reaching 3,939 MW, for which Inner Mongolia remains the leader in China and greatly surpasses the provinces such as Liaoning (1,245 MW), Hebei (1,143 MW) and Jilin (1,085 MW). The newly-added installed capacity in Chifeng, Inner Mongolia in 2008 was 500 MW, with the total capacity exceeding 1,000 MW, becoming the first city breaking the milestone of 10 MW in China.

The rapid growth of Inner Mongolia is due to the following factors:

Firstly, Inner Mongolia is rich in wind resources. A general survey shows that in Inner Mongolia the onshore 10-meter-high wind resource area with wind power density of more than 150W/m^2 is 1.05 million km^2. In the area, approx. 1,000 GW can be installed. The area has good quality of wind resources, non-destructive wind speed and plain terrain. It is favorable for broad wind farm. The provinces adjacent to Inner Mongolia, such as Heilongjiang, Jilin, Hebei, Shanxi, Gansu and Xinjiang, prefer to choose the areas near the boundary of Inner Mongolia for wind farm construction.

Another favourable factor of Inner Mongolia is its power grid conditions. The north and east side of Inner Mongolia connects with Northeast Grid, and with China Northern Grid in the middle. Although there is only independent regional power grid in the west of Inner Mongolia, it also has the conditions of connecting with Northwest Grid. The strong grid linkage has provided the assurance for wind power to be connected to grid. It is the advantage of Inner Mongolia that the other provinces such as Xinjiang cannot compete with.

Last but not least, the government shows great interest by taking measures to encourage and guarantee development of wind power industry. The government actively strives for concession tender projects, and accommodates some 10 GW-level wind projects. Some local governments in Inner Mongolia, such as Chifeng, Baotou, all made an ambitious development plan for wind power promotion. It is planned to build large wind bases in Hulunbeier in the north; Huitengxile and Wulanchabu in the middle; Saihanba in the east; and Bayanzhuoer and Baotou in the west of Inner Mongolia. The government pointed out that by 2010, wind power installed capacity would reach 5,170 MW, accounting for 7.5 percent of the total installed capacity. There is a series of supporting policies and measures issued by Inner Mongolian government to encourage various investors to build wind farms there. As pushed by rapid growth of wind power installed capacity, Inner Mongolia actively attracts wind turbine manufacturers to make investment and have localized production of wind power equipment, forming a complete industrial chain, which is integrated into the economic development of Inner Mongolia. Wind power equipment manufacturing zone has been created in Baotou, attracting some businesses to invest, such as Goldwind, Erdos Baofeng, Dong’an Group, Sanyi

Heavy Industry. And Vestas, Flanders, China Aerospace Science and Technology Corporation, Guangdong Mingyang, and Ruineng Beifang have set up their businesses in Inner Mongolia to prepare for competition.

3.9 Existing Problems and Barriers for Wind Power Development

China's wind power industry has developed very fast for the past two years with an unprecedented growth. However, it also can be seen that some problems and obstacles for development of wind power industry will appear in future by analyzing current situation and looking into future.

3.9.1 Grid Connection Problems

In 2008, the newly-added installed capacity was 6,240 MW in China, with the total capacity reaching 12,150 MW. The installed capacity of 12,150 MW mainly benefits from the existing resources of grid under the support of power grid operators. In the next few years, it is expected that China will still have 5,000 and 8,000 MW added newly each year. With regard to building large bases connecting with grid, since some of wind bases with 1 GW and 10 GW need long-distance and high-capacity power transmission, new transmission projects shall be built. Currently, although the technology of the power transmission system of the main grids with 220 KV and 500 KV has matured, it takes a long time for construction planning. To build 10 GW-level wind power bases and transmit wind power on a large scale in Xinjiang, Gansu, Inner Mongolia and other remote areas, it is necessary to build 750 KV or 1,000 KV, EHV, AC, power transmission systems or ±600 KV and ±800 KV, EHV, DC power transmission systems. These systems are still under testing, trial-manufacturing and commissioning, thus the pace of development cannot be fast. Therefore, even if a power grid company attaches great importance to and supports wind power development, in the next few years the 5,000-8,000 MW of wind power that will be connected to power grid will impose pressure on power grid construction. It can be estimated that in the next few years, the construction speed of wind farm in China will be subject to that of the power grid connecting with wind power projects.

Xinjiang is a typical area showing that grid can restrict the development of wind power. Since Xinjiang is an isolated small grid with the total installed capacity of only 8,000 MW, currently, the further development of wind power is hard when wind turbines of approx. 600 MW (approx. 7.5 percent) have been installed. The urgent issue to be solved is grid connection if Gansu builds the large wind power base. In Northeast and Inner Mongolia, wind projects are delayed due to difficult grid connection; wind turbines cannot be put into operation after installation; and wind power generation is limited at the time of low load. This is quite common. In the next few years, the situation will be worse.

3.9.2 Load Adjustment Problems

With 10 GW-level wind power being connected to the grid, besides transmission, it also needs to solve the problem of power consumption. Wind power is variable, thus brings tremendous pressure to load adjustment on the grid. The new problem resulted from wind power due to transmission, such as the switch and dispatch of electricity between provincial and large power grids and pricing, will challenge the existing dispatch and management mode of power grid. Currently, comparing with other technical problems of grid connection of wind power, such as reactive power regulation, static and dynamic stability, harmonic interference and voltage flicker, the adjustment of active power/load that might be the most important factor influencing the grid connection, which will be a key problem that has to be solved.

3.9.3 Possible Surplus Capacity

The potential annual capacity is estimated at 30,000 MW in 2010 for the wind power equipment assembly businesses under planning and construction in China, and might reach 60,000 MW by 2020, a great difference compared with the expected annual market demand of 5,000-8,000 MW. It can be predicted that supply deficit will appear in wind turbine market within the next few years. There are 70 businesses competing for wind turbine manufacturing. Most of them will face the danger of being eliminated. Some unfavorable situations will make the readjustment of wind power industry come earlier, such as adjustment of policies, less enthusiasm of investors for wind power projects and the entry of foreign wind turbine manufacturers into domestic market.

3.9.4 Turn the Tendency from Favoring Capacity to Favoring Production

For a long time, there is a tendency that China pays more attention to power installation capacity than power generation capacity and efficiency. In all plans and statistics, there is always data of wind power installed capacity, but no clear data on the level of generation. In fact, power generation is the final goal of installation, and the power output is essential for the efficiency of wind power projects. Currently, it is not easy to gather the correct data of running wind farms in China in terms of actual power generation. According to the statistics of 47 wind farms in 12 provinces and regions of China in 2007, Xinjiang was the highest with 2,401 utilization hours and Liaoning was the lowest with 1,325 hours. The average is 1,787 hours, having not achieved the expected 2,000 hours yet. According to the data in *2008 China Wind Power Development Results Statistical Report* issued by China's Hydropower Engineering Consultancy Group, by the end of 2008, the total production capacity of wind power was 9,386 MW, and the total grid-connected generation was 14,829,106 MWh, equivalent to 1,580 utilization hours on average. As a whole, the actual generation efficiency of China wind power still needs to be improved. The actual generation of most of wind power projects in China is lower than the expected figure. It is worth to consider and to learn lessons from the situation. If the constructed wind farms being put into operation successively for the past years have not yet generated profits after running for 2-3 years, this will lower the enthusiasm of investors for wind power projects, which is harmful to the sustainable development of wind power industry.

3.9.5 Pricing Mechanism to be Improved

Provinces and regions played a very important role in determining feed-in tariff of wind power. It should be avoided that there is a unified feed-in tariff for wind power in one region. Although most of provinces in China are large in area, the wind areas in the same province may vary in wind resource status. Taking Xinjiang as an example, its nine major wind areas are different from each other in wind resource. Based on the preliminary data of wind monitoring, the wind resources in some small wind areas such as Xiaocaohu and Santanghu are much different from those in Dabancheng. If they have the same feed-in tariff, the economic benefit/policy effectiveness will be very low. Although Guangdong has the feed-in tariff fixed at RMB0.689/kWh, but the wind condition in the west (such as Leizhou Peninsula) is clearly different from the east (such as Nan'ao). Therefore, it is wise and reasonable to set feed-in tariff based on natural conditions of each wind area.

4 Solar Sector

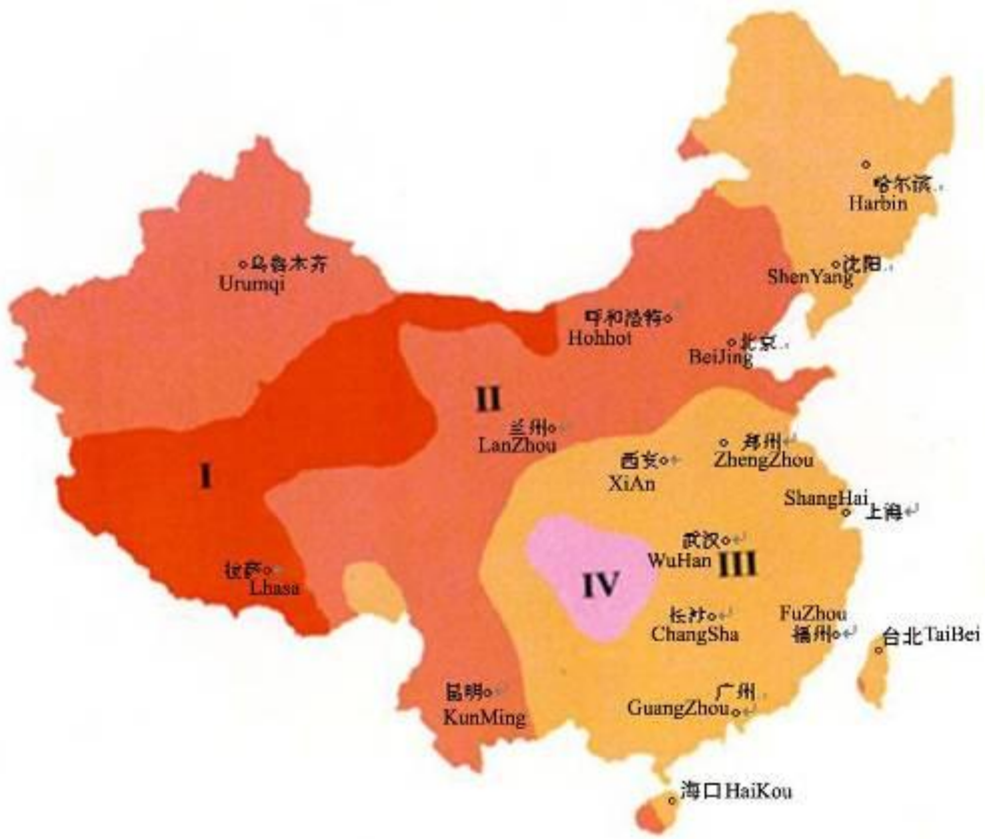
4.1 Solar Water Heater

4.1.1 Solar Resources

1. Introduction

China can be divided into four areas by annual solar radiation in1971-2000. As shown in Figure 2, the solar resources of the four areas are shown in Table 1.

Figure 2 Division of solar resource in China (Disregard Dongsha, Xisha, and Nansha islands)



Area of Excellent Solar Resource

In this area, the irradiation is over 1750 kWh/m^{2}a, and the ratio of the maximum number of available days to the minimum number of available days on a monthly basis is smaller. The annual change is steady. The belt has the best utilization conditions of solar energy. Most parts of Tibet, the southern part of Xinjiang, Qinghai, Gansu, and the west of Inner Mongolia are included in the belt.

Area of Very Good Solar Resource

In this area, the irradiation is 1400-1750 kWh/m^{2}a. The yearly change of available days is steady. But in Hengduan Mountains and the Southeast Coastline, the ratio of the maximum to the minimum number of available days on a monthly basis is over 2. The days on which solar energy cannot be used increase sharply. This belt includes the Northern Xinjiang, Northeast of China, Eastern Inner Mongolia, Northern China and the Northern Jiangsu, the Loess Plateau, the east of Qinghai and Gansu, the area from the West of Sichuan to Hengduan Mountains, the coastline of Fujian and Guangdong, and Hainan.

Table1 Distribution of Solar Resources in China (excl. Dongsha, Xisha and Nansha Islands)

Category	No.	Indicator (kWh/ m^2·a)	Percent of total land area of China	Areas
Excellent solar resource	I	≥1,750	17.4 percent	Most parts of Tibet, South Xinjiang, Qinghai, Gansu and West Inner Mongolia.
Very good solar resource	II	1,400-1,750	42.7 percent	Most parts of Xinjiang, the east of Qinghai and Gansu, Ningxia, Shaanxi, Shanxi, Hebei, the northeast of Shandong, the north of Inner Mongolia, the southwest of Northeast China, Yunnan, the west of Sichuan.
Good solar resource	III	1,050-1,400	36.3 percent	Heilongjiang, Jilin, Liaoning, Anhui, Jiangxi, the south of Shanxi, the northeast of Inner Mongolia, Henan, Shandong, Jiangsu, Zhejiang, Hubei, Hunan, Fujian, Guangdong, Guangxi, the east of Hainan, Sichuan, Guizhou, the southeast of Tibet, Taiwan

Modest solar resource	IV	<1,050	3.6 percent	The midland of Sichuan, the north of Guizhou, the northwest of Hunan.

Area of Good Solar Resources

In this area, the irradiation is 1,050-1,400 kWh/m^{2}a. The ratio of the maximum to the minimum number of available days on a monthly basis is over 2. The yearly change of available days is evident. The season with the minimum number is unfavorable for the utilization of solar energy. This belt includes: the Southeastern mountain of China, Han River, and Western Sichuan, Guizhou and Guangxi.

Area of Average Solar Resource

In the area, the irradiation is less 1050 kWh/m^{2}a, with the lowest solar radiation. This belt includes: the middle of Sichuan, Northern Guizhou and Northwest of Hunan. In the belt, there are only 1-2 days with solar radiation time of more than 6 hours in Chongqing. Besides July and August are the two months with average 18 days of solar irradiation of 6 hours, there are less than 9 days in the other months.

2. Review on Potential of Development and Utilization

During 1971-2000, the area that have more than 1,050 kWh/m^{2}a solar irradiation on a yearly basis (Category I, II and III) accounted for approximately 96 percent of the total land area. Except for Sichuan Basin and its neighbor areas, the solar resources of most of areas of China are better than or equal to that of other countries at same latitude, even much better than that of the countries in Europe, and Japan. Generally speaking, China's solar resources are rich, and the conditions of most areas enable solar energy resources to be popularized and applied. With the rapid development of China's economy, solar water heating (SWH) has been better popularized and utilized in China for the last decades.

4.1.2 Market Status

1. Market Size

In 1992, China's production of SWH reached 500,000 km^2, and accounted for 50 percent of the global output for the first time. China has been the biggest SWH producer ever since. In 1998, China's SWH output was 3.5 million km^2, with the sales revenue of RMB2.5 billion and the capacity in operation of 15 million km^2. In 2008, the output was 31 million km^2, with the sales revenue of RMB43 billion and the capacity in operation of 135 million km^2, accounting for 81 percent of the global output.

Table 2 Annual Output and Capacity of SWH in China (1998-2008)

Year	Total Output		Annual Growth (%)	Annual Output Value (RMB100)	Accumulative Capacity		Year-Over-Year Growth (%)
	Area (million km^2)	MWth			Area (million km^2)	MWth	
1998	3.5	2,450	--	25.0	15	10,500	--
1999	5	3,500	42.9	40.0	20	14,000	33.3
2000	6.4	4,480	28.0	60.0	26	18,200	30.0
2001	8.8	5,740	28.1	93.8	32	22,400	23.1
2002	10	7,000	22.0	105.6	40	28,000	25.0
2003	12	8,400	20.0	115.0	50	35,000	25.0
2004	13.5	9,450	12.5	150.0	62	43,400	24.0
2005	15	10,500	11.1	200.0	75	52,500	21.0
2006	18	12,600	20.0	270.0	90	63,000	20.0
2007	23	16,100	27.8	320.0	108	75,600	20.0
2008	31	21,700	34.8	430.0	135	94,500	25.0

In the 1990's, the State Economic and Trade Commission developed the 9th FYP and *2010 SWH Development Plan*. It was expected that China's SWH total availability would reach 13 million km^2 by 2000, and 43 million km^2 by 2010. The target of 2010 has been reached successfully in 2004. At the current speed, China's SWH total availability will exceed 150 million km^2 by 2010, and 300 million km^2 by 2020.

In 2007, the SWH per capita was only 83 m^2 per thousand persons. In 2008, it was 94 m^2 per thousand persons, less than that of the European Union.

2. Domestic Market

The market of China's SWH is classified into residential SWH market for urban areas, residential SWH market for rural areas and SWH market for organizations.

Residential SWH market for urban areas

SWHs are first introduced in urban areas in China. Since 1979 when China started the economy reform and opening-up, people's living conditions have been improved dramatically. In the 1980s, after the residents in towns have possessed colorful TV sets and refrigerators, domestic hot water use has become the important desire. Water heater is a necessity to meet the desire. In the 1990s, China carried out the housing policy reform shifting from welfare-oriented public housing to commercial housing. The housing condition of residents in urban areas has been improved stage by stage, bringing huge demand for SWHs. In this period, the technologies of SWH are improved continuously, with enhanced products and cost-effectiveness. Table 3 shows the comparison of cost-effectiveness of three types of SWHs. SWHs are increasingly popular among residents for their advantages such as energy saving, environment protection, safety and cost-efficiency. The market share of SWHs increased year after year, from 15.2 percent in 2001 to 50.8 percent in 2008. Table 4 shows the change of market share of three types of SWHs in 2001-2008.

Table 3 Comparison of the cost-efficiency of the Three Types of SWHs

Items	**Electric Water Heater**	**Gas Water Heater**	**Solar Water Heater**
Hot Water Supply (litre/day)	100	100	100
Equipment Investment (RMB)	1,200	1,000	1,800
Annual Operational Cost (RMB)	500	350	5
Lifetime (year)	8	8	10
Average Annual Investment in Lifetime (RMB)	650	560	185

Table 4 Market Share of the Three Types of SWHs (2001-2008)

Year	**Electric Water Heater (%)**	**Gas Water Heater (%)**	**Solar Water Heater (%)**
2001	30.00	54.80	15.20
2003	44.23	37.57	22.20
2005	45.20	26.57	28.23
2007	42.30	19.20	38.50
2008	49.2		50.8

Residential SWH market in rural area

Over the past few years, China has carried out the new countryside construction. Some local governments have installed SWHs for farmers, and give the farmers a subsidy of 30-70 percent for buying SWH. This promotes the expansion and popularity of SWHs in rural areas. In 2009, Chinese government lists SWH into the plan named "Household Appliances to Rural Areas", which will further promote application and expansion of SWH in rural areas. It is predicted that, by 2020, the availability of SWH in rural area and township will account for 60 percent. In the next decade, the residential SWH market for rural areas will become the largest one in China.

SWH market for public utilizations

Since the end of 1990s, the Chinese Government has paid more attention to environmental protection, and has implemented the policy using petrol or gas instead of coal in the public organizations in urban areas. By the end of 2000, small- and medium-sized boilers had been prohibited in most towns in China. These policies promoted the popularity and application of SWH systems. More and more hotels, schools, hospitals and factories are equipped with SWH system for environmental protection and lower running cost.

Since 2000, the concept to integrate solar energy into buildings has been put forward. It has gained remarkable achievement for nearly 10 years. China has issued 35 policies and laws related to it, which will promote the development of the integration. The integration will be a key market for solar energy engineering in the next decade.

In addition to this, SWH system can be applied in providing hot water for industry, heating, air-conditioning, drying, agriculture, aquiculture and desalinating.

3. Export

The export of SWH from China to the rest of the world has increased gradually since 2001. The gross export value of SWH was USD10 million in 2001. It reached USD65 million in 2007, increased by 5.5 times that of 2001. See Table 5 for the export of SWH in 2001-2007.

Table 5 China's Export of SWH (2001-2007)

Year	2001	2002	2003	2004	2005	2006	2007
Export Value (USD)	1,000	1,200	1,450	1,700	2,000	4,000	6,500
Growth (%)		20.0	20.8	17.2	17.6	100	62.5

China's SWHs have been exported to more than 80 countries and regions, including the developed countries like Germany, Italy, Denmark, the Netherlands, Japan, and Canada, as well as the developing countries such as Philippines in the Southeast Asia, Middle East, Africa, and South America.

The exported products include all-glass evacuated heat collecting tube, heat collector with evacuated tube, water heater with evacuated tube, flat plate SWH. They are mostly exported to 32 countries and regions in Europe, Africa and Southeast Asia. The all-glass evacuated heat collecting tube and the heat collector with evacuated tube are mainly exported to the developed countries in Europe. The water heater with evacuated tube and the flat plate SWH are mainly exported to the Southeast Asia and Africa.

4.1.3 Government Administration and Related Policies

1. Government Administration

China has shifted from Command Economy to Market Economy since 1975. In the era of Command Economy, the original State Development Planning Commission and the State Economic and Trade Commission were mainly in charge of the planning and development strategies of SWH industry. Prior to 1983, the pilot demonstration and technology commercialization of the industry was managed by the State Science and Technology Commission, and those of energy technologies for rural areas (including utilization technologies of solar energy) by the Ministry of Agriculture (MOA) since 1983. Since the end of 1990s, with the development of China SWH industry, NDRC has developed the planning and development strategies for the SWH industry to promote the integration of SWH into buildings, which is a tendency in the future. So the Ministry of Construction (MOC) started to take the lead of the pilot demonstration and technology commercialization of the integration.

2. Policies and Planning

In 1975, the original State Science and Technology Commission held the first National Experience-sharing Sessions in utilizing solar energy in Anyang, Henan Province. Since then the promotion and research of solar energy were incorporated into the state plan, receiving special funds and material support. Some universities and research institutions established the projects and departments for solar energy research. It unfolds an upsurge of solar energy R&D. In the 6^{th}, 7^{th}, and 8^{th} Five Year Plans, the state supplied a large number of funds to organize the research of SWH technology. A series of high grade technologies and products, such as all-glass evacuated heat collecting tube and heat collector with evacuated tube, have been developed successfully, laying a sound foundation for the commercialization of SWH in China.

In 2003, the UNF funded NRDC and MOC to carry out a project named "Global Practice in the Integration of SWH and Buildings and Its Reference to China". With the help of UNF, China has developed the standards and norms related to the integration, improved design plans, carried out pilot demonstration and organized visits to foreign countries. This accelerated the process of the integration of SWH into buildings. Some model communities for the integration have been set up in Beijing, Shanghai, Jiangsu, Yunnan, Shandong, Liaoning and Tianjin. The pilot demonstration also obtained better affects.

The ECL, which was implemented on January 1, 1998 and amended on April 1, 2008, has the provisions encouraging to promote and apply renewable and new energy sources like solar energy, and to use renewable energy systems during energy-saving reconstruction of new and existing buildings.

The ReLaw, which came into effect on 1st January, 2006, rules that the state encourages organizations and individuals to install and use SWH system, solar energy heating system and solar photovoltaic system. The State Council appoints the related departments to develop technical economy policies and technical specifications for the integration. Real estate developers are expected to provide the necessary conditions for the use of solar energy in the design and construction of buildings.

The Ordinance on Energy-Saving of Civil Buildings, which came into effect on 1st October, 2008, rules that the state encourages and supports to use renewable energy, such as solar energy and geothermal energy, during energy-saving reconstruction of new and existing buildings. The local governments in the places that have the condition of using solar energy are expected to take effective measures to encourage and support organizations and individuals to install and use SWH, solar lighting, solar heating and solar heating/cooling systems.

Since 2006, some local governments, such as Jiangsu Province, Baoding and Xingtai in Hebei Province, Sanmenxia and Nanyang in Henan Province, Yantai, Qingdao and Zibo in Shandong Province, Dalian in Liaoning Province, Hainan Province, and Anhui Province, have issued 35 local policies and regulations on the integration of solar energy and buildings.

From 2006 to 2008, MOC and MOF have implemented demonstration projects of renewable energy throughout the country. The projects are mainly for solar and heat pump energy-saving technologies.

With the above efforts, China has obtained a lot of experience in the integration of SWH with villa, multi-storey and small high-rise dwelling buildings, which lays a foundation for the future development.

3. Standards and Certification

Until recently, twenty national standards and three industrial standards for SWH industry have been issued, formed a standard certification system. In particular, in recent years, the original national standards have been revised for all-glass evacuated heat collecting tube, flat plate SWH, heat collector with evacuated tube, and residential SWH. And some new national standards were constituted, such as the *Technical Specification for Application of SHW in Civil Buildings* and the *Specification for Evaluation of SWH*. Some places have issued related local standards. They ensure the healthy development of solar energy industry.

At the end of 2008, the Solar Energy Standardization Committee was founded, with a dedication to the planning, development and review of national standards for solar energy industry. Up to now there are two state-level testing centers for solar energy products, and two certification centers, which are Golden Sun Certification Center (for product quality) and Ten Rings Certification Center (for environmental performance).

4.1.4 Industry Development

1. Scale

Over the past ten years, the SWH output and sales increased from 3.5 million m^2 and RMB2.5 billion in 1998 to 31 million m^2 and RMB43 billion in 2008 by nearly 8 times. According to 2007 statistics, there were more than 3000 SWH manufacturers of which nearly 50 had output value of over RMB50 million, with a market share of 46.9%; 25 had output value of over RMB100 million, with a market share of 31.2%; 4 had output value of more than RMB500 million; and 2 had output value of over RMB1.5 billion.

Table 6 shows the market share of leading businesses (2001-2007). According to the table, we can conclude that their market share is increasing year by year. The market share increased from 20% in 2001 to 46.9% in 2007. It was expected it would reach more than 50% soon.

Table 6 Market Share of Leading Businesses (2001-2007)

Year	Annual sales (RMB100 M)	Leading businesses (revenue over RMB50 M)		Large leading businesses (revenue over RMB100 M)	
		Annual sales (RMB100 M)	Market share (%)	Annual sales (RMB100 M)	Market share (%)
2001	93.8	18.8	20.0	12.2	13.0
2002	105.6	21.1	20.0	16.1	15.2
2003	115.0	34.5	30.0	20.2	17.6
2004	150.0	57	38.0	31.5	21.0
2005	200.0	90	45.0	48	24.0
2006	270.0	120	44.4	75	27.8
2007	320.0	150	46.9	100	31.2

2. Industry System

Up to now, China's SWH industry has formed an integral chain ranging from the raw materials to collector and water heater products. The industry includes manufacturing, marketing, design, equipment, and after-sales service. It has promoted the development of raw material sectors such as glass, metal, and insulation materials, as well as manufacturing sectors such as metal processing, welding equipment, evacuated equipment, rubber and plastic products, electrothermal tube, and electronic meters and instrumentation. By the end of 2007, there were 45 factories that produce raw glass for evacuated tube, 115 kilns, and 996 production lines for evacuated tube coating. The annual production of evacuated tube was 250 million pieces. The industry created more than 2.5 million jobs.

Raw glass production is mainly concentrated in Shandong, Hebei, Henan, Chongqing, and Zhejiang Provinces; evacuated tube production is concentrated in Beijing, Shandong, Jiangsu, Zhejiang, and Anhui; and SWH production is concentrated in Beijing, Shandong, Jiangsu, Zhejiang, Anhui, Guangdong, and Yunnan.

3. Corporate investment and financing

In recent years, many SWH businesses in China have increased investment, upgraded the production equipment and transformed technology. Some production lines were set up, such as automatic all-glass evacuated tube coating production line, enamel pressure water tank automatic production line, support production line, and fluorine-free foam insulation materials production line. Some businesses set up production bases in other regions of China and foreign countries. Meanwhile, some foreign businesses invested in china in the forms of wholly-owned factories or joint ventures. They mainly produce plate or evacuated tube heat collectors and most of the outputs are exported.

Since 2007 some civil and foreign investment and financing institutions began to set foot in China's SWH industry. Goldman Sachs Group and CDH International signed a letter of intent (LOI) with Himin Solar Energy Group in Shandong. They injected USD100 million into Himin in their first investment so as to promote the public listing of Himin. It is expected that more investment institutions will invest the SWH industry.

4.1.5 R&D

1. Research results

The 15-year period from 1978 to 1992 was the stage focusing on R&D of SWH industry. A series of scientific research results were gained, which laid the technical foundation for the future development of the SWH industry. The research results are as follows:

Since late 1970s China started to research and make solar energy absorbing layers. Beijing Institute of Chemical Technology, Tianjin University, Beijing Solar Energy Research Institute, Xi'an Institute of Chemical Engineering, and Solar Energy Research Institute of Xinjiang used spraying and sol-gel technique to make different solar coatings like lead sulfide paint, acrylic resin paint and so on. Tsinghua University, Beijing Solar Energy Research Institute, Institute of Electrical Engineering, Chinese Academy of Sciences, Liaoning Environmental Protection Research Institute applied chemical and electrochemical technology to make selective solar absorption coating like PbS/Al, black chrome, and electroplating nickel. Tsinghua University, Beijing Solar Energy Research Institute, Institute of Electrical Engineering, and Liaoning Environmental Protection Research Institute employed magnetron sputtering technology to make selective solar absorption coatings like Al/N/Al and Cu/N/Al.

The endothermic board and structure of the flat plate solar collector were improved. The thermal properties of flat plate collector were enhanced. In 1987, Beijing Solar Energy Research Institute introduced copper and aluminum composite plate production line from Canada and succeeded in developing the coloring by anode oxidation on aluminum surface of the plate. After that, it developed anodic oxidation coating production line for continuous electroplating. These enabled China's production capacity of flat-plate collector to reach the international advanced level. Product quality has been recognized by the international market. Products are exported to Europe and South East Asia. After the successful development of Cu-Al composite strip production line, 18 similar production lines were made successfully by other metal processing businesses and domestic production of Cu-Al composite strip production line was realized. In addition to the board core of aluminum composite strip, all-copper high-frequency welding strip was also developed. After entering the 21st century, ultrasonic welding strip for flat-plate collector is introduced and developed by Chinese businesses.

In 1979, Tsinghua University, Shanghai Institute of Ceramics under Chinese Academy of Sciences, and the Second Glass Factory in Shenyang started to undertake research in all-glass evacuated tube collector prototype. Tsinghua University constantly improves the design and process of glass tube sealing, especially the selective coating materials and process. They have invented the single-target magnetron sputtering coating equipment and made Al/N/Al selective coating. The coating can be bonded onto glass surface firmly and has an excellent cost-effective performance. Tsinghua University researched and made the evacuated tube collector header that is simple in structure, easy in operation, and low in cost. Several all-glass evacuated tubes can be equipped into a collector by the header, which creates a good condition for the wide application of all-glass evacuated tube.

Since 1986, Beijing Solar Energy Research Institute, in cooperation with Dornier of the former Western Germany, conducted research and developed heat pipe evacuated heat collecting tube and collector, and solved the problems in heat pipe design and glass-to-metal seal. Commercialized production of the glass-metal heat pipe collector tube was achieved. The R&D of heat pipe evacuated tube with glass - metal seal was included in Beijing Sci-tech Program, pilot research projects, pilot base projects, and industrial revitalization projects. Small batch production was achieved. On this base, it was selected as the national "double plus" project. The institute set up Beijing Sunda Solar Energy Technology Co., Ltd. in partnership with Germany's Daimler-Benz. It has all intellectual property rights. A production base with China-made equipments was established.

In 1990’s, all-glass heat pipe evacuated tube was produced in China. In recent years, some businesses marketed it as a new product whose performance is to be tested by the market.

2. Pilot & Demonstration

Since 2006, MOF and MOC began to set up nationwide demonstration sites for the integration of solar energy and buildings, with subsidy provided. Though the efforts, China has obtained many experiences in the integration of SWH and various types of residential housing, laying the foundation for future development.

In recent years, in implementing the New Countryside Demonstration Program, many places have implemented the pilot projects of solar hot water and heating, and have accumulated rich experiences in promotion and application of SWH and solar heating in countryside.

In 2008, SWH system was used in many Olympic Venues and athletes apartments, playing a demonstrating role. So did the Qinghai-Tibet Railway Lhasa Railway Station Housing Project that adopts solar heating.

4.1.6 Barriers and Recommendations

1. Key problems

China's SWH industry has reached a new stage. However, several issues are still waiting to be addressed.

Involvement of multiple departments in the administration hinders the industry growth

Over the past 30 years, China's SWH industry has experienced three stages: R&D, commercialization, and upgrading. In these three phases, especially the first two, the government has played a key role in providing support and guidance. The future trend of China's SWH industry is the integration of solar energy into buildings. This involves many sub-sectors such as planning and design, construction design, design of water, power, heating and solar systems, supportive solar products and system installation. The SWH businesses are in a passive position. The planning and construction design are the key elements. Therefore the coordination and information exchange among those sub-sectors are essential. However, China's SWH industry administration policies and rules come from different departments which result a lack of effective communication and coordination. These problems will have an influence on its development in the future.

Lack of innovation in products and technology

The technology breakthrough in all-glass evacuated tube played a key role in the development of China's SWH industry. The technology and other matching technologies have been mastered by most of the businesses. Currently, products are lack of innovation. Increasing scientific research and technological input and upgrading products are the main challenges waiting to be addressed.

Market disorder and poor regulation

Because the technology threshold is low and it does not require much capital and high technology to start with, the market is therefore filled with unregulated small businesses, which causes intense market competition. Some companies with low quality final products and lack of after-sale services have heavily damaged the reputation of the industry.

Unregulated installation services and safety risks

The current design and SWH installation companies vary by their quality of services. Due to the lack of professional training provision and industry regulation, it has resulted installation below certain standards and caused safety risks. Therefore the urgency to regulate the installation companies is high.

4.1.7 Industry Trend

Evacuated tube solar collector and water heater will still be the key products in the near future. Compact in-line all-glass evacuated tube SWH will be the main product for the rural market. In urban area, the technology and products which adapt to the integration of SWH and buildings for villa, multi-story and high-rise residential housing will be the mainstream. Product quality and reliability must be further improved to increase productivity and lower cost.

Low-temperature solar hot water system integration technology includes efficient heat collection and storage, electromechanical integration and operation, auxiliary energy, control, measurement, and integration with buildings. It is mainly used in schools, hospitals, hotels, sport facilities, and residential buildings that need hot water. In addition, solar thermal utilization in industrial and agricultural production will be a big market in future.

Solar heating technology is the future direction of development. Efforts are needed to intensify the development and launch suitable products and technology to meet the needs of the market.

Efficient flat plate collector technology should be developed. The solar absorption ratio of coating should be about 0.92, the emission ratio no more than 0.1, solar transmittance of glass cover about 0.9, and the first heat loss coefficient no more than 4 $W/m^2 \cdot K$. In order to realize the industrial production, advanced production equipments must be provided.

Efforts should be made to develop 80-250℃ middle and high temperature solar collector technology to broaden the use of solar heat in areas such as industrial and agricultural production, textiles, food, chemical, cooling, air-conditioning and desalination. Efforts should also be made to develop active and passive solar housing technology, air heat collector, and solar cookers. Research and development of solar thermal power technology should be conducted.

4.1.8 Recommendations

1. It is urgent to regulate the SWH industry in a systematic way. It is recommended that the ministry which has integrated management functions take the lead to coordinate relationships among various parties as early as possible. Communication and collaboration should be strengthened to guide the sustainable development of China's SWH industry.

2. Further define the support policies for the SWH industry and include SWH products into CDM programme. Give support to the financial, credit, taxation aspects. Publish the mandatory policy of SWH installation in buildings to promote further development of the industry. Subsidize the vulnerable groups and undeveloped areas when they install SWH.

3. Increase scientific and technological input and address the technical bottlenecks in integration of solar energy and buildings, middle and high temperature solar collectors, solar heating and cooling, so as to provide technical support to upgrade solar water heater industry.

4. Strengthen market regulation, enhance efforts to investigate and deal with fake and shoddy products, and build good market order for fair competition.

5. Regulate the installation service businesses, implement the installation permitting system, strengthen staff training and installation regulation, set up professional installation team, ensure installation quality, and minimize the level of installation risks.

6. Emphasis on the SWH standard development and enhance product quality testing.

7. Strengthen international exchanges and cooperation, increase publicity efforts, explore actively the international market and export more SWH products to the rest of world.

4.1.9 Case Study

The solar resources in Kunming, Yunnan Province is very rich. Its average annual sunshine time is more than 2250h, and the average annual solar radiation is 5400MJ/m^2. The climate is humid and warm. The four seasons are all like spring, which make the city a suitable location to install SWH.

In the process of promoting SWH, solar energy manufacturers, building design institutions, and real estate developers cooperate with each other and realize the unity in planning, building design, solar system design and construction, to lead to an integration of SWH in buildings. SWH is a requirement for real estate developers in constructing new houses.

By the end of 2008, the penetration of SWH in Kunming had reached 30%, being the first in China. According to Kunming's development plan, by 2010, the penetration of SWHs will reach 50% in Dianchi Lake valley that covers 2,920 km^2, and 70% in demonstration region. The buildings with solar energy will account for 90% of the newly-built ones. The penetration of SWH in urban area is 60% and 20% in rural area. The installed capacity of SWH will reach 3.5 million m^2. By 2015, the buildings with solar energy will account for 95% of the newly-built ones; the penetration of SWH in urban area will be 70% and in rural area 35%; and the installed capacity of SWH will reach 6 million km^2. Kunming will take the lead in exploring the new road of developing solar industry and become China's solar energy demonstration city.

4.2 Solar PV

4.2.1 Status Quo of Polysilicon Industry

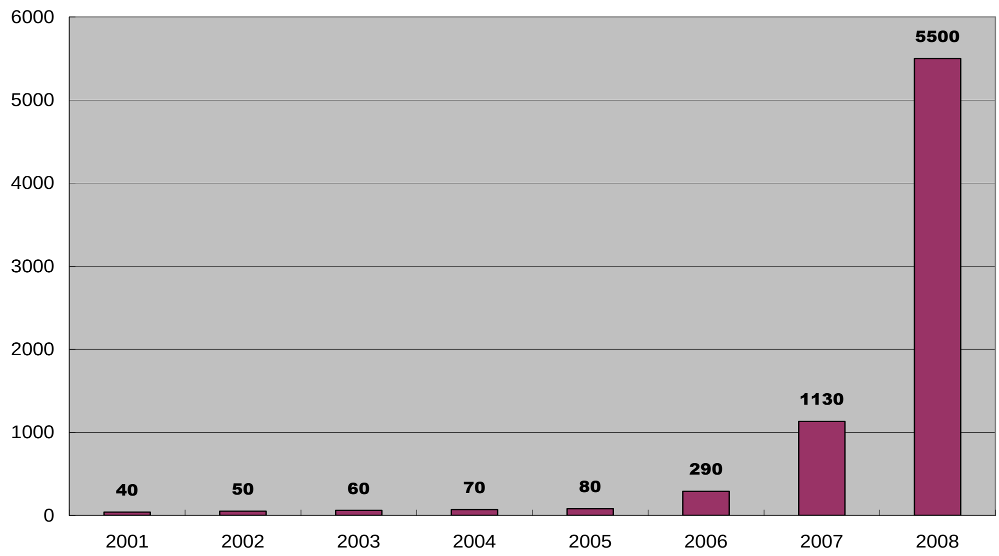
The crystalline silicon solar cell remains the mainstream of commercialized solar cell nowadays. In international market, over 90 % of solar cells are made of high purity polysilicon. As the most fundamental materials in PV cell, the high purity polysilicon has become the most significant part in

PV industry chain. Production of polysilicon kept an annual output of tens of tons for many years. This is the biggest barrier for the PV Industry development in China. More than 90% of the material needs to be imported, which has caused a rapid increase of price. Since 2005 the support to polysilicon production was enhanced. Some businesses such as Luoyang Zhonggui, Xingguang, and Xuzhou Zhongneng have developed their production capacity since 2007. The production was over 1,000 t in 2007 and 5,500 t in 2008. The polysilicon price was held back (see Table 7 and Fig 3).

Table 7 2005-2008 High Purity Silicon Production and Capacity (tons)

Company's name	**2005**		**2006**		**2007**		**2008**	
	Cap.	**Prod.**	**Cap.**	**Prod.**	**Cap.**	**Prod.**	**Cap.**	**Prod.**
Ermei Semiconductor	100	80	100	105	200	155	700	500
Luoyang Zhonggui	300	—	300	185	1000	520	3000	1000
Sichuan Xinguang	—	—	—	—	1260	230	1260	800
Xuzhou Zhongneng	—	—	—	—	1500	150	4000	1800
Wuxi Zhongcai	—	—	—	—	300	55	300	200
Shanghai Lengguang					50	20	40	40
Chongqing Daquan							2000	60
Total	400	80	400	290	4310	1130	20000	5500

Figure 3 China Polysilicon Production, 2001—2008 (tons)

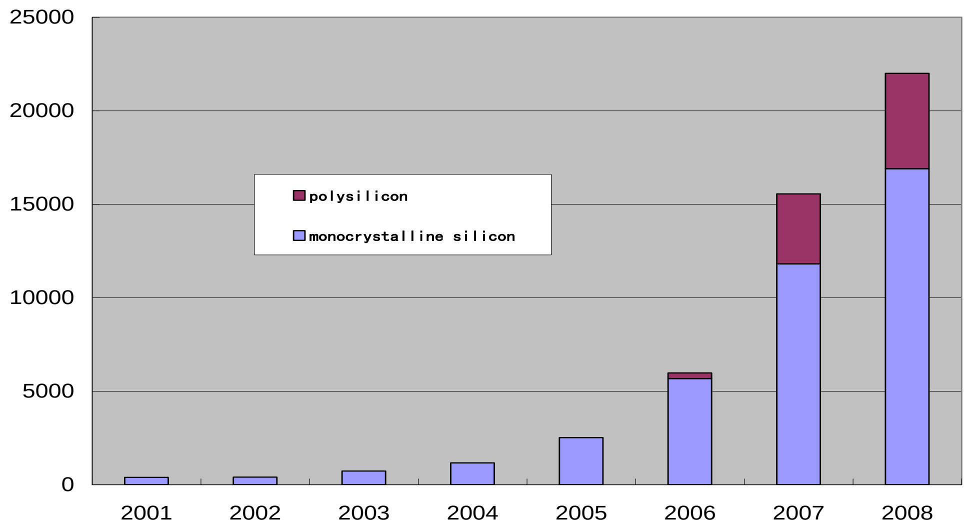


The polysilicon industry sees booming although there are still various issues in its development. China still lags behind the international level in processing, mainly in terms of product purity and energy consumption per unit of output. Very few companies really master the core technologies. Many producers have not solved the problem of recycling materials. So the recovery rate is not high. According to the statistics, by the end of 2008, about 40 domestic companies were constructing, expanding and planning the polysilicon production line with modified Siemens process, with total capacity of over 100,000 tons and total investment of over RMB100 billion. Phase 1 sees a capacity of over 40,000 t and investment of over RMB40 billion. Phase 1 construction started from 2006-2010 and will be completed in 2007-2010.

4.2.2 Status of Silicon Ingot and Wafer Manufacturing Industry

The manufacture of solar-grade silicon ingot and wafer is the second step of the PV industry chain. Driven by PV market in recent years, the manufacturing industry keeps pace with it and witnesses the healthy and rapid development as well. By the end of 2008, there were over 70 factories engaging in the production of silicon ingot/wafer in China. The total output of ingot was 11,810 t, 108% more than 5,680 t in 2006, where the growth of polysilicon was 231% and monocrystalline silicon ingot was 77%. By the end of 2008, there were 60 ingot and wafer manufactures with total production capacity of 30,000 tons, and the total production were 22,000 tons. The solar-grade ingot production is shifting from monocrystalline silicon to polysilicon which is the mainstream at the global scale, indicates that China's ingot industry is becoming increasingly mature.

Figure 4 Solar-grade Crystalline Silicon Ingot Production, 2001-2008 (tons)



The domestic mono-silicon pulling technology is relatively developed and the mono-silicon furnace has been produced by Chinese companies with low cost. The mono-crystal pulling is featured by small investment, short construction period and capital payback period. The production of mono-crystal silicon ingot continues to dominate the market. The polysilicon casting furnace depends on the import and its price is expensive. But the growth rate of polysilicon ingot exceeded that of monocrystalline silicon since 2007. In 2007, the production of polysilicon ingot increased by 234% over 2006, while that of monocrystalline ingot increased by 77%. Now LDK in Jiangxi is establishing the largest production base of polysilicon ingot/wafer in the world. With the localization of polysilicon casting furnace in China, the proportion of polysilicon casting ingot will continuously increase and catch up with the international trend.

4.2.3 Status of Solar Cell Manufacturing Industry in China

1. Crystalline silicon solar cell

The total production of solar cell was 438 MWp in 2006, including 12 MWp amorphous silicon cell and 426 MWp silicon cell, and 1,088 MWp in 2007, including 28.3 MWp amorphous silicon cell and 1059.7 MWp silicon cell. The growth rate in 2006 and 2007 against previous year were 201％ and 148.1％ respectively, which signifies sustained rapid growth. In 2007, the total solar cell production were 1,088 MWp, becoming the biggest solar cell manufacturing country surpassing Japan (920 MWp) and Europe (1062.8 MWp). By the end of 2007 the number of solar cell manufacturers was more than 50 and the production capacity reached 2,900 MWp of which 100MWp was amorphous silicon film cells. The production in 2008 was 2,500 MWp (including 500 MWp in Taiwan).

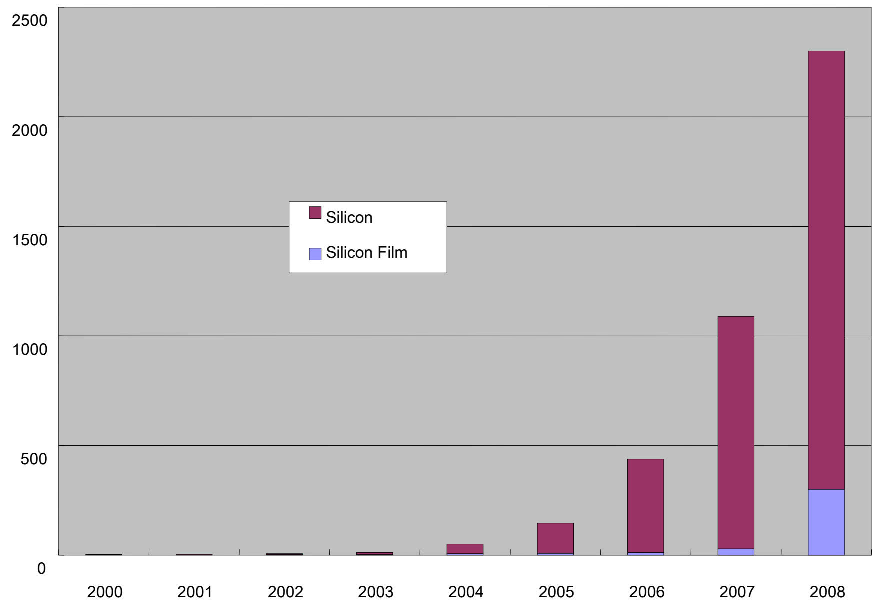
2. Amorphous silicon solar cell

Since the introduction of single-junction amorphous silicon cell in late 1980s, China’s amorphous solar cell industry has been on the track of steady development. In this century, it sees rapid development. The shortage of polysilicon materials in recent years stimulates the thin-film cell development. By the end of 2007, the number of businesses producing thin-film solar cell amounted to 20 with the total production capacity of 80MWp. In 2006 and 2007, the production of amorphous silicon cell was up to 12MWp and 28.3MWp respectively.

The rapid development of the thin-film cell industry is driven by several factors: pull by world PV market; the technology of thin-film cell is getting mature; and the shortage of solar-grade polysilicon materials has restricted PV development.

The figure below shows the solar cell production from 2000 to 2008. It is obvious that the solar cell in China began its robust development since 2002 and it surged at extraordinary rate. The figure 5 shows the production and growth tendency of silicon solar cell.

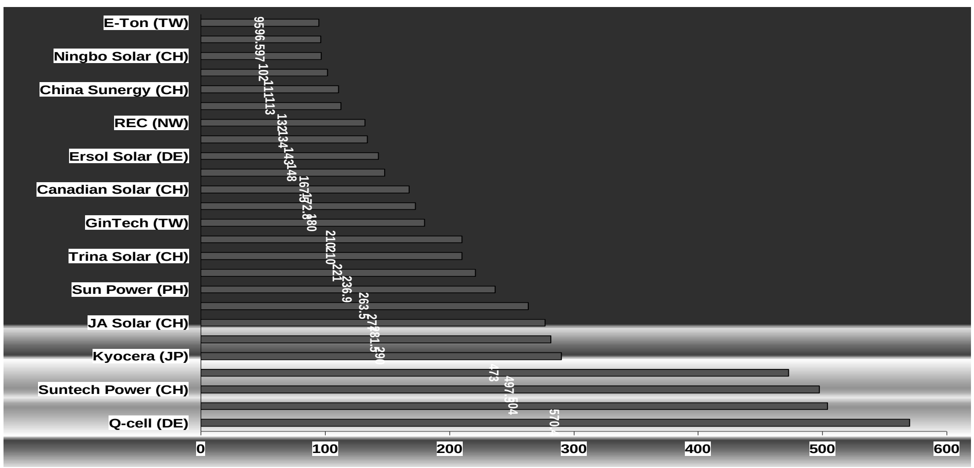
Figure 5 Silicon Solar Cell Production in China (MW), 2000-2008



The solar cell industry can be characterized by the rapid development with explosive growth rate. The actual production of solar cell in China was 1,088 MW in 2007, ranking first in the world. According to the statistics on ENF website, there were already over 62 Chinese businesses engaged in the production of solar cell in 2008. The total capacity is 3,000 MW and the production of solar cell is about 2,000 MWp, one third of world total, ranking the first place in the world.

From PV NEWS (April 2009)，the new statistics shows that the World Top 25 PV Manufacturers have a total production of 5,726.6MW. Eight manufacturers are in the Mainland of China with total production of 1,814.3MW and four in Taiwan of China with total production of 640.5MW.

Figure 6 World Ranking of PV Manufacturers and Their Production



However, the high-end equipments for PECVD, automatic production, solar cell automatic inspection, sorting, plasma etching, and automatic screen printing still depend on import. The thin-film solar cells give priority to binary junction amorphous solar cell. There is big gap between China and foreign countries in terms of commercialization of CdTe solar cell and CIGS solar cell.

4.2.4 Status of Module Encapsulation Industry

The PV module encapsulation industry, as part of the whole PV industry chain, is featured by most developed production technology, the highest localization rate for its equipments, the lowest access threshold, the largest number of businesses, the fastest expansion and the largest production. Majority of homemade PV modules are exported abroad, especially to European countries as the result of domestic PV market that has yet to be mobilized. However, the current production capacity for encapsulation is oversupplied but with meager profit due to the scarcity of silicon feedstock in the upstream. The product quality is mixed. The international competitive edge is limited. And the potential for development is not promising.

PV module encapsulation industry is a labor-intensive industry. The labor cost in China is lower. The module encapsulation capacity is larger than solar cell production capacity. So some foreign solar cells are encapsulated in China. That is why the module output is higher than cells. For example, Q-cell of Germany, the world largest solar cell manufacturer, produced 570 MWp cells in 2008. All of the cells were sold to other module manufacturers. This is the typical labor division in PV industry. China’s PV module encapsulation is more competitive than that of the developed countries.

China’s PV modules production industry is characterized by established technology, lower technical requirements, less investment, large amount of participating companies, low localization rate, intensive labor, meager profits and mixed product quality. There are in total 330 companies in solar cell encapsulation industry and the total capacity in 2008 was 4,000MW accounting for over 40 % of the world total, according to the statistics on ENF.

4.2.5 PV Balancer of System (BOS)

All of the components of the PV system except for PV array are called BOS, such as controller, inverter, MPPT, data acquisition, display, transportation and monitor, batteries, power distribution systems, framework and wires etc.

The controller/inverters are the core components that are very essential for increasing the system efficiency, reliability and lifetime of the system as well as for reducing system costs. The localization of controller and inverter is catching up with the international level. Most of the standalone PV system and 100-150 kW grid connection controllers and inverters are developed and produced domestically. Partial large on-grid PV systems (≥100kW) are imported from other countries.

4.2.6 Related Manufacturing Equipment and Special Materials Industry

The related manufacturing equipments primarily include a number of equipments used in each part of the chain and the related materials refer to the special materials used in the industry.

The China-made mono-Si manufacturing stove can satisfy the requirements of PV industry, and the price is only 30%-50% of the imported products. The manufacturers of mono-Si furnace totaled over ten in 2007 and over 800 sets were sold in the year. The domestic demand could be met while some products are exported.

With regard to the manufacturing equipments for wafer, the wire saws used in wafer manufacture are mainly imported, but the localization is expected to be realized soon and its popularization will be imminent. With regard to the manufacturing equipments for solar cell, the production of diffusion furnace, plasma etching machine and dryer has been localized. The encapsulation equipment of PV module and testing equipment have been produced in China. And the special materials in PV industry such as the quartz crucible, the POCl3 and Al plasma, the ultra-white low iron glass, the EVA are also produced domestically.

4.2.7 Social-economic Benefits

The employees in PV industry in 2007 amounted to about 100,000 and the sales revenue was up to RMB100 billion. The employees in PV industry in 2008 were estimated to be 200,000 and the sales revenue reached RMB200 billion.

4.2.8 PV Technology Application and Market Development

Promoted by Chinese government, China's PV market develops rapidly in the 21st century. By the end of 2008, the accumulated installed capacity reached 140 MW (see Table 8). The PV market development since 1980 is as follows:

Table 8 China's PV Market Development Since 1980 (kW)

Year	1980	1985	1990	1995	2000	2002	2004	2006	2007	2008
Annual installed capacity	8	70	500	1550	3300	20300	10000	10000	20000	40000
Accumulated installed capacity	16.5	200	1780	6630	19000	45000	65000	80000	100000	150000

4.2.9 Rural Electrification Program

The national plans like "Tibet No-electricity Counties Electrification Project", "China Brightness Project", "Tibet Ali PV Plan", "China Rural Township Electrification Program" and "No-electricity Areas Electrification Program" have been created and implemented in recent years. Chinese government also takes every opportunity to apply for the international assistance and has implemented many international cooperation projects, such as WB/GEF/NDRC "REDP Project". The rural renewable energy electrification projects have been promoted greatly.

After the implementation of the largest scale rural PV power electrification program in China even in the world -"Song Dian Dao Xiang (SDDX)" program financed by the NDRC in 2002, the "No-electricity Areas Electrification" pilot demonstration program was conducted by the Tibet DRC in March 2008. The bidding was conducted in Rikaze, Naqu and Shannan. In total, 2500 sets of User PV System (UPS) were purchased, among which 655 sets for Naqu, 452 sets for Ali and 1393 sets for Rikaze.

4.2.10 Building Integrated PV

During "The 9th Five-Year Plan" and "The 10th Five-Year Plan" periods, several urban grid-connected PV power generation and Large Scale PV (LSPV) projects were implemented. *The ReLaw* entered into force in 2006. NDRC, MOST, MOC, MOF, MII, and MOA promote the PV technology application actively. Many PV power generation projects were started. To honor the promise of "Green Olympics" after the successful application of Olympic Games, several BIPV projects and 135,000 PV street lights were installed in Beijing and the total capacity amounted to 10MW. The 100kWp grid-connected Building Integrated PV System (BIPV) at the Olympic National Gymnasium is shown below.

Figure 7 National Olympic Gymnasium, 100kWp BIPV

Figure 8 Zhejiang Yiwu1.29MWp BIPV

4.2.11 Large Scale PV in Desert

On the November 22, 2007, the *Notice of Requirements on the Buildings of Large Scale Grid-connected PV Project* was issued by the NDRC General Office to the 8 western provinces. It was required in the *Notice* that the scale of the LSPV power station could not be less than 5MW, which should be clearly declared in the pre-feasibility studies submitted by the provinces. On the July 21, 2008, the feed-in tariff of 4 RMB/kWh for Inner Mongolia Erdos Concentration PV Cells Power Station (205kW) and Shanghai Chongmingdao (1MWp) were approved by NDRC Price Authority (Fagaijiage 〔2008〕 No.1868). Both of the two projects are large scale power generation grid side connecting projects, supplying power to 10 kV and 35 kV power grids directly. At the end of 2008, the bidding of Dunhuang LSPV project with capacity of 10 MW started. All of these projects provides an encouraging beginning, predicts that the incentive policies to LSPV projects' feed-in-tariff have been implemented and LSPV is coming into a flourishing development stage.

Figure 9 LSPV Grid Connected PV Pilot System in Yangbajing of Tibet, 100kWp

Above is the first domestic LSPV grid connected system in Yangbajing of Tibet. It was installed by Electrical Engineering Institute and provided a test basis for LSPV grid connected technology research facilities.

4.2.12 Incentive Policy

The ReLaw has been approved by the National People's Congress (NPC) Standing Committee on February 28, 2005 and be enacted on January 1, 2006. *The ReLaw* is similar to the Germany "Feed-in tariff" policy. A PV project developer should pay the initial investment. Their investment and profits will be paid back through selling PV power after the project is approved by the government. The power utilities should buy all of the electricity generated by PV systems according to the reasonable feed-in tariff. The excess cost between the PV power and traditional power should be shared in the national grid by levying additional tariff on electricity users.

The *Interim Procedure for the Distribution of Renewable Energy Power Price Additional Income* (Fagai Price [2007] No.44) was published by the NDRC on January 11, 2007. It is regulated in the *ReLaw* that the excess between the expenses incurred in the purchase of average power price generated with conventional energy shall be shared in the selling price. In 2006, RMB0.001 was added in the power retail price to subsidize the renewable power generation businesses. In order to guarantee that the related power generation businesses can get their subsidies in time, detailed methods were prescribed in the *Interim Procedure*.

The General Office of the State Council forwarded on August 2, 2007 the *Energy Saving Power Generation Deployment Method (trial)* co-published by NDRC, State Environmental Protection Administration, SERC and Energy Office. In this method, the power utilities are asked to deploy renewable in priority under the condition of safe power supply according to the principle of economy and energy saving.

The *Regulatory Measures on Off-take Purchase of Electricity from Renewable Energy Sources by Grid Companies* was published by SERC in 2007 (enacted on September 2007). This paper emphasizes that the power utilities must purchase renewable in priority referring to *the RE Law* and provide grid-connection service. (The grid connecting costs also could be shared in the power price levied towards the electricity users.)

On March 23, 2009, *the Opinion on Speeding up BIPV Application (No.128 Caijian 2009)* set out by MOF. It makes clear that China upholds the solar roof plan and uses the leverage effect of financial policy. Thus, the mechanism guided by the government and developed by the PV market is established. It accelerates the commercialized PV development consequently. At the same time, the *Notice on Subsidizing BIPV Application (No.129 Caijian 2009)* was printed and distributed. It proposes that the subsidy is standardized to be RMB20 /Wp in 2009 and the specific subsidy will be defined according to degree of integration of BIPV, technology advancement in PV projects, etc. The standard subsidy will be adjusted appropriately in the light of industry development. Furthermore, from the China National Economic Stimulus Package, it clear identifies the role renewable energy is playing in the economic recovery. With a view to the above incentive policies, the domestic PV market in China is expected to be flourishing soon.

4.2.13 Barriers Faced by PV Market

1. The impact of financial crisis

In the second half of 2008, the world was impacted by the financial crisis, and the international PV market declined dramatically. As 98% of Chinese PV cells were exported to the international market, China PV industry was hit greatly. The products cannot be sold and a lot of manufacturers' production lines were stopped or suspended. Some businesses even went bankrupt. The stocks of the leading PV businesses which listed in the overseas stock market were depreciated. The financial chain fractured. The PV industry is facing an unprecedented challenge.

2. Domestic market to be started

The hit of international financial crisis to China PV industry could only be relieved by the domestic market. The prosperity of domestic market is essential to the spread of PV technology domestically and the sustainable development of China energy and environment. The main barrier faced by domestic PV market is the inefficient implementation of PV-related policies in *ReLaw*. For example, there is absence of clear feed-in tariff and pricing mechanism for PV power generation. The approval procedures of PV project are unclear at this stage. In 2009, NDRC conducted open bidding for Dunhuang LSPV (10MW). It's hopeful that a reasonable price level can be worked out through the bidding system which has been experienced by China's wind Industry.

3. Lack of public technology R&D platform

Combined with the large scale building of standalone PV systems and on-grid PV systems, quality evaluation of PV systems, on-site testing technology, new evaluation method of PV power generation, grid connection technology are becoming more and more important. The existing experimental and testing conditions are far behind to satisfy PV products performance testing requirements, and the building quality of PV projects cannot be guaranteed sufficiently.

It is meaningful to establish national PV R&D center for enhancing the core technology and comprehensive technology indicators of PV industry. The establishment of a sustainable PV industry supporting system includes fundamental R&D, key technology, industrialized equipment production, public research and testing accreditation platform etc.

4. Weak technical standards and management regulations

Especially for the grid-connected PV power, the technical standards and management regulations on safety, power quality and management that are concerned by the power utilities should be published as soon as possible. In addition, for the BIPV systems, the related installation standards and management regulations should be developed by cooperating with the design institutions to remove the barriers of accepting PV power by the construction sector. This will be helpful for the development and market growth of PV power systems.

5. Lack of sustainable human resource capacity building system

With the development of PV industry, the related training activities, organizations and mechanism begin their development as well. But with the prediction of explosive growth of PV industry in the coming 15 years, in order to satisfy the huge training demands from vocational education, university education even public awareness dissemination, a comprehensive, sustainable and capable training system is important.

6. Suggestions on China's PV industry development

To enlarge the domestic market at a suitable time

In accordance with the *Medium- and Long-term Plan for Renewable Energy* proposed by the NDRC and the "Feed-in-Tariff" policy, governmental departments (including NDRC, MOST, MOC, MOF, MII, and MOA) should cooperate together to enlarge the domestic market.

PV power technology can be promoted through the building of rural standalone PV and PV/wind hybrid power stations, RE micro grid power systems, and the construction and demonstration of solar lighting, BIPV and LSPV systems. This can also stimulate the economy and domestic demand.

To establish public technology R&D platform

To establish the National PV Projects Research and Demonstration Base, PV system and components public research platform and experiment and testing platform to provide public resources for the industry development, and to provide technical supports and experiment and testing conditions for the mass production of si material, PV cells and modules, balance of components like controllers, inverters and tracking systems.

To develop and update related technical standards and management regulations

It is suggested that the development and upgrade of the related technical standards and regulations should be enhanced. Some technical standards should be developed with the cooperation of different departments. For example, the BIPV technical standards cannot be developed without the participation of PV system application units but also can not without the participation and support from the construction sector and power utilities. Otherwise, though the standards could be developed they cannot get the approval or acceptance of other related units. It will fail to play the role of market regulating and stimulation.

To establish the sustainable human resource capacity building system

In order to guarantee the realization of PV Industry Mid- and Long-term Development Plan and goals, it is essential to make a clear investigation of the PV industry human resources and their distribution, and to develop the human resource capacity building mechanism in accordance with the development goals. The training organizations should emphasize qualification accreditation to guarantee the training quality.

The national human resource capacity building plan can be realized through university and vocational education to provide training to the following human resources: the comprehensive human resources in charge of decision-making, technology and management; senior technicians responsible for advanced technology application and innovation; technicians responsible for project design, implementation, testing and accreditation; and the technicians and managers serving the projects directly. This human resource capacity building plan will lay a good foundation for the PV industry development and play an essential role in the realization of PV industry mid- and long term development plan and goals.

5 Biomass Power Generation

5.1 Introduction

5.1.1 Biomass Sources

In this report, biomass sources for power generation include: agricultural crop straws/stalks, agro-product processing residues, forest residues, wood mill residues, livestock rejecta, municipal wastes, industrial organic wastes including solid wastes and sewages.

5.1.2 Biomass Power Generation Technologies

Biomass power generation technologies covered in this report include electricity from direct combustion of biomass (includes direct combustion of bagasse), mixed combustion, biomass gasification (includes rice husk gasification at rice mills), biogas, waste incineration, and landfill gas sources.

5.1.3 Sector Development Status

Power generation from biomass, especially from bagasse fuel, has been applied in China since 1960s. In 1989, China's first garbage power generation facility was completed and most other biomass power technologies have been started since 2005. The most important driver for biomass development in China is *the RE Law* that was promulgated in 2005 and came into force since the beginning of 2006. A system of supporting policies after that has greatly promoted biomass power sector development in China. The following table 9 depicts annual biomass installations. By the end of 2008, the total installed biomass power capacity in China had exceeded 3,136 MW.

Table 9 Annually Installed Capacity of Biomass Generation Technologies (MW)

Year	Bagasse	Direct Combustion	Gasification	Rice Husks	Waste Incineration	Land fill Gas	Biogas	Total
1985	600							600
1990	800				18			818
1995	800				50			850
2000	1000				100			1100
2001	1000				120			1120
2002	1500			2	150			1652
2003	1700			15	180			1895
2004	1700		1	25	210			1936
2005	1700		1	40	300	5	30	2071
2006	1700	25	6	42	360	13	86	2219
2007	1700	367	10	45	462	32	125	2709

2008	1700	592	18	50	603	45	173	3136

5.2 Resources and Economic Potentials

5.2.1 Crop Straws/Stalks and Agro Processing Residues

1. Crop straw availability

Agricultural crop residues (straws and stalks) are the most important biomass sources in China. In 2006, the output of seven major crops including rice, wheat, corn, beans, oil plants, cotton, and potatoes was 525 million tons (Mt), which brought about 736 Mt straws.

Table 10 Production and Straw Yields of Major Crops in China, 2006

Crop	Rice	Wheat	Corn	Beans	Potato	Oil seeds	Cotton	Total
Production (million t)	182.57	104.46	145.49	21.05	34.06	30.59	6.75	525.49
Straw yield (million t)	182.57	104.46	290.97	42.10	34.06	61.19	20.24	735.58

Note: Agricultural production data from *China Statistics Year Book*, NBS.

Agricultural residues include rice husks, corn core, and bagasse from agricultural processing, such as grain processing facilities, food production, sugar making and breweries. These residues are of huge amount and easy to collect. For example, rice husks, as major rice processing residues, can account for 20% of total paddy weight. They are mainly produced in Northeast China, Hunan, Sichuan, Jiangsu and Hubei. Corn cores are obtained after threshing, about 20% of corn cob, mainly from Liaoning, Jilin, Heilongjiang, Hebei, Henan, Shandong and Sichuan, while bagasse is a principal by-product from sugar industry, accounting for 50% of sugar cane weight. Sugar cane is mainly planted in Southern China--Guangdong, Guangxi, Fujian, Yunnan and Sichuan provinces. Biomass from the above three sources can be 100 Mt in total, or 50 million tce.

2. Resources and developing potentials of available crop residues

In 2006, about 115 Mt agricultural residues from seven major crops were returned to soil as fertilizer, accounting for 15.7% of total straw yields. As for the agro-residues, 122 Mt, or 16.5%, were used as feedstuff; 227 Mt, or 30.9%, were used by households for fuel; 36 Mt, or 4.9%, were used for industrial purposes; and thus about 235 Mt, or 32% of total straws, were left unused.

If the 235 Mt crop straws are used for energy, e.g. for power generation, 235 billion kWh electricity would be produced. Suppose a 7,000-hour annual operation, these straws can provide fuels for a 33

GW thermal power capacity.

5.2.2 Livestock Rejecta

1. Resource availability

According to the livestock farming data from *China Animal Husbandry Yearbook*, in 2006, a total of 1.84 Gt of livestock rejecta and 1.28 Gt of urine were produced in China, totaled 3.12 Gt. Livestock types and their waste yields are summarized as in the following table.

Table 11 Major Livestock Wastes Produced in China (2006)

Animal	Inventory (thousand)	Rejecta (kg/d)	Urine (kg/d)	Total Rejecta (million t)	Total Urine (million t)
Cow	13632	30.00	18.00	149.267	89.56
Bull	125810	20.00	10.00	918.415	459.208
Pig	494407	2.50	3.00	451.147	541.376
Sheep	368966	1.50	0.50	202.009	67.337
Poultry	2509125	0.13	0.13	119.058	119.058
Total				1839.897	1276.539

2. Exploitable potentials for energy

Livestock waste for energy can only be possible for large animal farms, while rejecta resources from households and small livestock farms are not suitable for power generation. By the end of 2005, 3746 livestock biogas projects had been developed in China, which only account for 0.11% of scale animal farms. Among them, there are 700 large biogas projects, only accounting for 6.6% of large and medium animal farms.

For example, a 3,000-pig farm can produce 1400 t of manure that can generate about 60,000 m^3 biogas with the heat value of 5,500 Kcal/ m^3. Using current technology, 120,000 KWh electricity can be produced each year, assuming that the utilization hours are 3000 and the capacity is 40 kW. Therefore, from the annual 67.75 Mt livestock wastes produced by large animal farms, a total of 3.05 billion m^3 biogas can be produced annually, or 6.1 billion kWh electricity can be generated. Assuming that the utilization hours are 3000, the total installation capacity could be 2.03 GW.

Along with improved life quality and changed food consumption mix, grain consumption is decreasing and meat demand is increasing. China's livestock farming will keep a stable growth. In addition, because of increased animal farming cost and requirements for management techniques and agricultural product export, individual farming will be gradually replaced by larger size animal farms.

The improved environmental awareness and national pollution control policies will also help further large-scale livestock biogas project development in China.

5.2.3 Forest and Wood mill Residues

1. Total resources

Firewood forest

Firewood forest is one of the five major forest types in China, mainly used for providing fuels. Since 1980s, firewood forest plantation has been significantly developed. According to the sixth national forest resource survey, there are 3.03 million hectare firewood forests with wood volume of 56.27 million m^3. It is estimated that 66 Mt firewood biomass is currently available in China.

Forestry residues

Forestry residues include logging residues, wood mill wastes, branches and small timber from forest management.

Forest logging and wood mill residues

A sample survey found out that biomass from logging and forest management (including small trunks, branches and leafs) will account for 40 % of total forest biomass. Currently, China has mature forest and over-mature forest areas of 14.69 million hectares with volume of 2.74 b m^3 and total biomass of 3.214 Gt. The over mature shelter forest and special- purpose forest covers 307,750 hectares with volume of about 713 million m^3 and total biomass of 836 Mt. Therefore, the total biomass from logging and replacement can be as much as 4.05 Gt. Taking 40% residues, the total residue biomass can be about 1.62 Gt, although the forest logging should be carried out year by year with restriction of quotas and regulations.

Residues from wood processing (including barks, wattles, board skins, parings and saw dusts)

During the period of 11th five-year plan, China has increased logging amount for industrial materials in its national quota. In particular, in recent years, short-cycle rotational plantations by various social entities for as industrial materials are ready to be logged. Pilot projects for commercial forest and agricultural shelter forest management in national forest reserve areas are getting expanded. Thanks to these efforts, the wood yield in 2006 reached to 66.12 million m^3, an 18.91% over 2005 level. In overall timber production, logs contributes 61.12 million m^3 (excluding firewood). In addition, China imported 32.14 million m^3 logs in 2006. So China's total log processing was 93.25 million m^3. According to a sample survey of timber mills and estimation by experts, the biomass from timber processing residues can be 34.4% of logs. Therefore, it can be estimated that residues from national timber mills will be 32.08 million m^3, or 28.87 Mt.

Biomass from forest management

According to the regulations from National Forest Administration, young forests need 2-4 intermediate cuttings during the growth, yielding wood biomass of 6.0 m^3/ha (20 % intermediate cutting intensity). The forest management can produce 551 million m^3 small-dimension wood, or 500 Mt biomass. Conifer and broad leaf forest are pruned 2-3 times, producing 184 Mt branches. Adding the two items, 684 Mt biomass will be expected.

Shrubs

China has a total of 45.2968 million hectares of shrub land. According to shrub planting areas of provinces and biomass from a unit area, the biomass from shrubs is 300-400 Mt.

Others

Biomass from other sources will be available at about 100 Mt, including the biomass from pruning cash tree, bamboo, shrubs in forest, seedling and urban plants.

2. Exploitable Potentials for Energy

Forest biomass resources are constrained by not only natural conditions such as forest species, distribution, age and yields, but also national forestry policies and regulations. The biomass availability also depends on many economic conditions, such as market demand, collection, transport, and processing cost-effectiveness. There are some competitive uses of the forest resources as well. It is estimated that a total of 160 Mt forest biomass can be used for energy, equivalent to 92 Mtce.

Table 12 Available Forest Biomass for Energy

Sources	Resources （Mt）	Availability（Mt）	Conversion(Mtce)
Firewood forest	66	66	37.71
Logging residues	131	26	14.86
Processing residues	29	29	16.57
Shrub management	42	25	14.29
Other sources	100	15	8.57
Total	368	161	92

5.2.4 Municipal Solid Wastes

There are 656 cities currently in China, including 4 provincial cities, 283 prefecture-level cities, and 369 county-level cities. In 2006, the urban population of China was 577.06 million, producing 148 Mt municipal solid wastes, equivalent to 257kg per capita.

5.3 The 2007 New Installation and the Gap from 2010 Goals

5.3.1 2010 Development Goals

It has been clearly indicated *the Medium- and Long-term Plan for Renewable Energy in China* issued by NDRC that installed capacity for biomass power will be up to 5.5 GW by 2010.

The specific plan also proposed that during 2006-2008, 200 MW demonstration projects from agricultural residues biomass and the same capacity from forest biomass will be developed respectively. By 2010, the total installed capacity for biomass power (including bagasse generated electricity) in China will be up to 4 GW.

5.3.2 Accumulated Installed Capacity by 2008

By the end of 2008, a total of 3.136 GW biomass generation capacity had been installed in China, including: 1.7 GW bagasse power; 592 MW biomass direct combustion power; 18 MW biomass gasification; 50 MW rice mill power generation (off-grid self-powering systems); 603 MW waste combustion power generation; and 173 MW biogas power generation, including 45 MW landfill gas and sewage biogas power.

5.4 Current Policies and Regulations for Biomass Power

According to *the State Council Investment Management Regulations*, a power generation project over 50MW capacity would need to be approved by NDRC. Smaller power projects can be awarded by provincial energy authorities. Because of resource constraints for biomass power generation projects, most of single projects are under 50MW, and hence approved by provincial level government authorities and registered with NDRC.

In terms of agro-residue biomass power generation projects, there was no biomass fuel facility installed before 2005. In order to promote the applications, NDRC approved three demonstration projects: Shandong Shanxian County Biomass Power Plant (owned by NBE Biomass Electricity), Hebei Jinzhou Biomass Power Plant (owned by Hebei Provincial Buildings Investment Co.), and Jiangsu Rudong Biomass Power Co. (owned by Jiangsu Guoxin Investment).

Based on the RE Law, a series of biomass power supporting policies has been promulgated as follows:

Guidelines for Renewable Energy Sectors: brief description of renewable sectors, technologies, and equipments encouraged by the State. This has laid a foundation for further formulating and implementing sector policies and financial incentives in China.

Management Measures for Power Generation from Renewable Energy Sources: elaboration of regulatory regime, project management, and grid connections for renewable power.

Interim Management Measures for Renewable Power Tariff and Cost Allocation: specific provisions of legal tariff and cost sharing.

A special fund for renewable energy development has been included by MOF in its budget. The *Management Regulations for Renewable Energy Special Fund* has been issued. Policy for financial subsidies and tax incentives will be formulated according to the *Guidelines for Renewable Energy Sectors*.

SERC issued *the Regulations on Off-take Purchase of Electricity from Renewable Energy Sources by Grid Companies*. Specific management regulations have been enacted.

NDRC Pricing Department issued *the Interim Measures on Renewable Power Surcharge Collection and Allocation*. The department and SERC published *the Notice on Scheme for Renewable Power Tariff Subsidies and Quota Trading*, implementing tariff subsidy for renewable power generators.

On 19 September 2007, the first category of renewable power tariff subsidies was announced with RMB250/MW subsidy for renewable power generators operating from Jan to December 2006. Later, two new categories of subsidies were enacted for renewable power generators in January-September 2007 and October 2007-June 2008. In addition, to compensate the loss caused by increase of feedstock price in biomass power, an interim subsidy of RMB100/MW was awarded to the generators that use agricultural and forest residues as feedstock starting from October 2007.

5.5 Investment Status and Sector Development Trend

5.5.1 Estimation of Investment in Newly Installed Capacity

In recent two years, biomass direct combustion power generation technology has become a major contributor to newly installed biomass capacity. Before December 2006, there had been no biomass-fueled power generation capacity in China until the breakthrough project of NBE Shanxian biomass power plant completed in December 2006 with installed capacity of 25MW. By 2007, there had been 16 biomass combustion power generation projects with total installed capacity of 367MW. Another 30 projects were added in 2008 with total installed capacity of 592MW. Among them, the NBE Shanxian project has the highest investment of RMB337 million, with static investment per unit of capacity up to RMB13,800/kW, while the indicator in other projects was reduced. For example, the static investment for projects completed in 2007 was RMB11,000-12,000/kW, while the investment for projects completed in 2008 was reduced to RMB10,000-11,000/kW.

Investment of biomass gasification power generation projects is lower than that of direct combustion power projects. Unit investment for biomass gasification projects equipped with complete gas purification system is estimated to be nearly RMB6,000/kW.

Solid waste incineration power generation technology is also an important part of new biomass power installation in recent years. By the end of 2008, a total of 603MW capacity had been installed for power generation from waste. Investment for grate waste incinerator would be about RMB280,000-330,000/daily processing of per ton waste. If fluid bed technology is adopted, the cost would be about RMB250,000-3 million.

A rice husk power generation facility would cost about RMB750,000-850,000, with typical installed capacity between 160 kW and 200 kW.

5.5.2 Investment Entities

Bagasse biomass power generation projects are generally invested by sugar mills.

Currently, straw direct combustion generation facilities are mainly invested by large or medium state owned companies, e.g. NBE Biomass Power Co. which is held by the State Grid Corporation of China.

Among the newly developed biomass direct combustion projects, only the Inner Mongolia Wushenshaliu Project was invested by a private company. The project was developed by Inner Mongolia Gujinfang Energy Co. and invested by Beijing Jinru Real Estate. Another privately invested project is the Henan Changge Thermal Power renovation project. Two other biomass-fueled power projects at Baoying and Lianyungang were invested by Hong Kong Golden Concord Holdings Limited.

Investment in biomass gasification projects is generally from private companies.

Rice husk power generation projects are mainly developed by rice mills. Most of them are private owners.

Similar with rice husk projects, livestock farm biogas projects are mostly constructed by animal farms, generally privately owned.

Solid waste incineration power generation projects are invested by both state companies and private sector, generally through BOT, while some projects are invested by local governments.

5.5.3 Status of Biomass Power Sector

1. Straw (and forest residue) direct combustion generation projects

Biomass direct combustion power generation technology is a new technology deployment in China. The first biomass direct combustion power project was installed at NBE Shanxian Biomass Power Plant in December 2006. The project uses Danish BWE technology. With total investment of RMB337 million, the installed capacity of the project is 25 MW.

By the end of 2007, a total number of 16 biomass direct combustion projects have been completed with total installed capacity up to 367 MW, of which NBE Biomass Power invested 10 projects with 250 MW capacity (8 projects of 25 MW and 2 projects of 12 MW). Other biomass power projects include: Suqian Biomass Power Plant invested by China Energy Conservation Investment Corporation (CECIC), 24 MW; Jinzhou Biomass Power Plant invested by Hebei Construction Investment Corp., 24MW; Jiangsu Huai'an Biomass Power Plant invested by Jiangsu Guoxin, 24 MW; Baoying Biomass

Power Plant (15 MW) and Lianyungang Biomass Power Plant (12 MW) by HK GCL; and Henan Changge Thermal Power Plant, 15 MW.

In 2008, 29 biomass direct combustion power projects were completed with total installed capacity of 618MW. These biomass projects were mostly developed in Shandong, Jiangsu, Henan, and Hebei. A few projects were also developed in Northeast of China, Xinjiang, Anhui, and Hubei provinces.

In developing biomass direct combustion power generation projects, NBE (NBC) Biomass Co. is the leader that contributed 68% of the biomass power capacity in 2007. By the end of 2008, this situation had changed. For example, by 2008, the company completed six new projects with total capacity of 72MW, 12MW each. The accumulated capacity was 322MW. However, by the end of 2008, the nationwide installed capacity had reached to 618MW and NBE’s market share reduced to 54%. Although still the largest investor in biomass power market, many new investors have entered the sector.

2. Bagasse power

Power generation from bagasse has long been applied for sugar cane mill power supply and in general merely operates during production seasons. Bagasse generation facilities are mainly installed in Guangdong, Guangxi, and Yunnan provinces. By 2002, the installed bagasse power capacity had been up to 1.7 GW. Electricity generation from bagasse depends on sugar yield and production. Since 2002, China’s sugar cane yield has been maintained at about 90 Mt annually and sugar product at nearly 9 Mt. Therefore, the installed bagasse power capacity has been kept at 1.7 GW.

Most of the sugar mills in China use 3.9 Mpa boiler generation unit, while 6 Mpa or even 8 Mpa units are used at large foreign sugar factories so that extra electricity generated can be transmitted into the grid. In order to boost local economy, higher voltage equipment systems are currently installed for turbine systems and chemical factories (it was regulated by Guangdong Province ten years ago that 6Mpa or higher pressure would be required for newly installed boilers) in order to largely reduce energy consumption. According to international practice, the back-pressured turbine systems, if increased from 3 MPa steam at 400℃ to 6 MPa at 500℃ can increase electricity generation to 36%. If increased to 8.5 MPa at 525℃ it can improve productivity by 65%. Large sugar mills should take the leading role in installing the new technologies. Of course, higher pressure turbine systems should be more strictly managed by improving boiler water quality, production management, and operational staff skills. Greater efforts should be made before system is put into operation.

3. Biomass co-combustion technology

Biomass co-combustion power generation is the most cost-effective and most efficient scale biomass power generation technology. It is widely applied in developed countries as a mainstream technology. However because of the biomass consumption measurement and regulatory problems in China, specific subsidy policy has not been worked. This has led to the fact that the technology cannot be advanced.

Shandong Shiliquan Power Plant is the first biomass co-combustion facility developed in China. With a 140MW turbine system, the plant uses 20% biomass fuel for co-combustion. This project is a pilot in the province and hence subsidized by a tariff at RMB240/MWh. The subsidy is awarded by Shandong provincial government, instead of national RE surcharge incentives.

Another co-combustion pilot is developed by GCL's at Baoying and Lianyungang in Jiangsu Province. The two project plants are experimenting to increase biomass ratio finally to 80%. According to national incentive policies, projects with over 80% biomass co-combustion can be subsidized through renewable power tariff. However, without authoritative accreditation, the project is unable to get the subsidy. Taking these into account, the two plants built a direct combustion boiler respectively in 2008 and received subsidy. Now the co-combustion boilers are renovated to direct combustion boilers to obtain the subsidy.

4. Biomass gasification power generation

Biomass gasification power generation technology is especially suitable for China due to its large population, less arable land, and dispersed biomass resources. So far, only one biomass gasification technology has been deployed, i.e. the circulating fluidized bed gasification facility developed by Chinese Academy of Science. By using a gas engine driven generator system, China's first project was completed at Jiangsu Xinhua Daiyao Township in May 2006 with installed capacity of 5.5 MW. Currently, 4 projects using similar technology have been developed with total installed capacity of 18 MW.

Since circulating fluidized bed technology is used, the produced gas contains high content of oxygen. Hence the electrical tar capturing technology cannot be applied. The high tar content in the gas would block the engine driven turbine system. Meanwhile, dregs containing tar are not well processed. Therefore the technology is still immature.

Some private companies are undertaking R&D on fixed bed gasification power generation process and have achieved breakthrough in key technology. The demonstration project based on the process is under construction.

5. Power generation from rice husk gasification

Rice mill husk generation projects are developed in several Chinese provinces such as Jiangsu, Anhui, and Shandong by private rice mills, usually small. These off-grid rice husk biomass power facilities use small fixed bed gasification-engine turbine process, with installed capacity of 160 kW, mainly for self-use. This type of projects is usually cost-effectiveness and hence develops fast since 2002. So far, there are nearly 300 facilities with a total of 50 MW capacity installed. Problems to be solved include lack of proper gas purification process and short continuous working time of the engine system. Generally, the engine combustion system needs to be cleaned and maintained every 15 days.

The rice husk gasification projects are deployed in Jiangsu, Anhui, and Shandong, Guangdong, and Heilongjiang provinces.

6. Biogas Power

Electricity from biogas has developed rapidly in China since 2005. By the end of 2008, a total of 173 MW biogas power capacity had been installed across the country, including 79 MW or 45.7% from light industries (alcohol and brewery, starch, citric acid, paper making), 45 MW or 26% capacity from municipal wastes (landfill gas, sewage biogas), and 31 MW or 17.9% from livestock biogas.

Three grid-connected livestock biogas power projects have been developed so far in China, including 1 MW capacity at Mengniu Diary Group, 2 MW at Beijing Deqingyuan, and 3 MW developed by Shandong Minhe Group. Challenges for biogas power projects in China include small capacity, connection to grid, and lack of incentive policies.

7. Power generation from solid waste incineration

52.15% of municipal wastes can be processed in three ways: landfill, compost, and incineration. There are 324 landfill sites that can process 206.6 kilo tons (Kt) wastes daily, 20 large compost facilities can process 9,500 t, and 69 incineration sites can process 400 Kt solid wastes each day.

In 1988, China's first solid waste incineration power generation facility was developed in Shenzhen by using two 150t/day capacity Martin type incineration furnaces made by Mitsubishi. This is the first solid waste incineration power generation project in China- Shenzhen Qingshuihe Solid Waste Power Plant. Now the 12 MW power plant processes 400 t municipal wastes daily. There are nearly 80 similar solid waste power plants developed in China currently with total installed capacity of 603 MW.

Grate incinerator technology is generally deployed internationally. In order to make higher temperature in the furnace and effectively decompose the extreme poisonous dioxins, liquid or gas fuels are injected into the furnace. About half of the Chinese projects are using this technology.

Among the developed solid waste generation facilities, about 40 projects are using the circulating fluidized bed furnaces. This type of furnaces can effectively decompose the dioxin toxicosis, thanks to the even internal temperature and high temperature at furnace exit. The cost is 20-30% lower than grate incinerator. The Chinese circulating fluidized bed technology is developed by Zhejiang University and Tsinghua University and is highly recognized internationally. However, because a certain proportion of coal is added into the solid waste incineration, it has the similar problem with biomass co-combustion technology in terms of lacking effective measurement and regulations. Because of this, solid waste power projects using this technology are unable to enjoy tariff subsidy.

8. Landfill gas power generation

Over the recent years, landfill sites in China have focused on landfill gas utilization and some active landfill gas collection and combustion technologies are deployed at selected sites. A group of landfill gas power projects are developed by taking landfill gas as clean alternative energy. These projects include Hangzhou Tianziling project, Wuxi Taohuashan, Nanjing Shuige, Guangzhou Datianshan. Electricity generated from landfill gas has been connected to grid for selling. After purification, landfill gas at Anshan Yangeryu site has been utilized for vehicle fuel.

5.5.4 Biomass Generation Development Trend

Biomass power generation is one of the most effective biomass utilization technologies. For example, a 25MW biomass direct combustion project can consume more than 200 Kt biomass. Hence, direct combustion power generation is the dominated biomass power generation technology in China, while other technologies have not been rolled out due to some technical or regulatory obstacles. We expect that development trend of biomass power generation will be as follows:

- Overall biomass power generation in China will be scaled up further. It is expected that by 2020, the total installed biomass power generation capacity will be over 20 GW.

- Biomass power generation technologies will be diversified instead of maintaining the current direct combustion as a single technology in China. Biomass power market will be shared by direct combustion, co-combustion, gasification, solid waste, and biogas technologies. Choice of technology will be focusing more on local resources.

- It is expected that biomass co-combustion will develop fast in coming years and gradually become a dominant technology in biomass power. However the premise is successful application of the measurement device for feedstock consumption, as well as tariff incentives based on the measurement technique.

- Appropriate size (5-10 MW for a single project) biomass gasification technology will be widely deployed. The mainstream of the technical scheme will be co-generation of gas, heat and power. The main application is the supportive power system in building small cities and towns. Investment in some projects will come from private investors and be managed under the local utility system.

- Development of biomass power generation sector, especially electricity form biomass direct combustion and co-combustion is expected to shrink once cellulose ethanol is commercialized. Large amount of biomass feedstock will be used for biofuel production. It is expected that by 2030, except for some utility biomass power generation projects, such as solid waste and gasification power, other biomass power projects will gradually be abolished.

5.6 The Impact of Biomass Power Generation on Farmers and Rural Area

5.6.1 Promoting Rural Development and Increasing Farmers' Income

Take the example of NBE Shanxian project, with installed capacity of 25 MW, the plant consumes 150-200 Kt agricultural residues each year. The current in-field straw price is RMB150/t. The average destination price would be at RMB300-400/t after adding cost for collection, processing, and transport. This can result in an increase of RMB54-60 million income annually for local farmers. In addition, local farmers are hired for straw collection, processing, and transportation activities. The plant can provide about 1000 jobs for local people.

Suppose 5 GW new biomass power capacity is installed, 40 Mt agro and forestry biomass will be consumed annually and local farmers' income can be increased by RMB10 billion and 250,000 job opportunities can be created. It is of great significance for increasing the income of local population, enabling industry to return to agriculture, and promoting Socialist New Village Program in China.

5.6.2 Improving Rural Life Quality and Promoting the Development of a Resource-saving and Environment-friendly Society

Turning the agro and forestry residues into commodities after collection and processing can overcome pollution caused by field burning and benefit rural development. According to estimation, a 25 MW biomass power plant can replace about 50 Kt fossil fuels, reduce 180 Kt CO_2 emission and 1 Kt SO_2 discharge. If the total installation of agro and forestry biomass power generation capacity is 5 GW, it can reduce 36 Mt CO_2 and 200 Kt SO_2 emission. This will greatly contribute to rural and urban environment protection.

5.6.3 Promoting County-level Economy and Providing New Job Opportunities for Rural Labor Force

Testing shows that a 25 MW unit, if its annual utilization is 6000 h, can produce electricity of 130 GWh and add value of RMB100 million. Straw collection, processing, and transportation will provide nearly 1,000 jobs. It will facilitate rural employment, local financial income, and service sector development. The biomass power development will also help stimulate rural economy and improve agricultural competitiveness of China.

5.7 R&D

5.7.1 Current R&D efforts

Bagasse power generation technology has a longer history in China compared with other biomass power technologies only started in the past few years. For instance, China's first biomass direct combustion project was developed and completed in the end of 2006. Only three grid-connected biogas projects were developed in China, all of them were put into operation in 2008. The first solid waste incineration power project was built in 1988. But only after 2002 the technologies with proprietary IPR started to be deployed.

So far, achievements have been made in agro and forestry residue power generation boiler, waste incineration power boiler, complete sets of medium and large biogas systems, and biogas internal-combustion generation unit. However, China is still new to the biomass gasification system and biomass collection machinery and technology.

5.7.2 R&D on Biomass Power Generation Boilers

Biomass power generation boilers are critical equipment in biomass related technologies, including boilers for bagasse power, direct combustion, and solid waste incineration.

1. Bagasse boilers

Bagasse boilers are mostly manufactured by Chinese suppliers. With mature manufacturing techniques, some products are exported to Southeast Asian countries. However, most of the Chinese bagasse boilers are operating at mid-temperature and mid-pressure. R&D on system efficiency need further enhancement.

2. R&D on biomass direct combustion boilers

Biomass direct combustion systems are developed in recent years. Among the established projects, half of them are developed by NBE Group, using Danish BWE technology and equipments that are manufactured in China. Some core technology and critical components such as vibration components for grate still need to be imported.

Wuxi Huaguang Boiler Co. Ltd is a leading Chinese manufacturer for biomass direct combustion boiler system. Among the 15 established biomass power projects that are not owned by NBE, nine of them are using Wuxi Guanghua Boiler products, a total of 13 boilers with the installation capacity of 162 MW. Another 10 projects are under construction.

3. Solid waste incineration boilers

The first group of solid waste incineration boilers was grate boilers, mostly imported Matin type, accounting for half of the deployed projects. At the late of 1990s, the circulating fluidized bed incineration boilers were developed jointly by Zhejiang Jinjiang Group and Zhejiang University. By using the high temperature in the hearth of boiler, dioxin can be effectively reduced. Meanwhile, the circulating fluidized bed technology suits more types of unclassified waste, being applicable to China. After 2000, the technology has witnessed fast development in waste incineration. So far, about 40 projects are using this technology with total installed capacity of 250-300MW. The solid waste incineration boiler developed by Chinese Academy of Sciences and Tsinghua University are also using the circulating fluidized bed technology.

5.7.3 Large Biogas Generation Projects

Large and medium-sized biogas power generation projects have a relatively long history in China. However, only after year 2000 the technology has developed more quickly. Although technologically mature, obstacles for deployment still exist. As one of the major challenges, most of the projects are invested by livestock farms. Technical service systems are rather poor. In addition, due to small scale, grid connection can be difficult, which restricts the industrial development.

In China, a 10,000-pig farm can be considered a large one. Suppose biogas projects are developed in the farm for electricity, only 100kW capacity can be expected. Large installation means larger animal farm. Higher cost in disease prevention would prevent project expansion.

5.7.4 Biogas Internal Combustion Generation Unit

The existing biogas internal combustion generation units in China are mainly renovated from conventional diesel-driven generation units and mostly developed by Chinese suppliers. Major suppliers include Shandong Shengli Oil Field Power Machinery Group, Jinan Diesel Engine Factory, Qidong Baoju Power Machinery Plant, and Nantong Haihe Power Equipment Ltd. Over 312 biogas power generation units have been produced and sold by the four manufacturers with total capacity of 105MW, or 60.8 % of total biogas installed capacity in China and 85.4% of total domestic manufacturing. Other manufacturers include Weifang Diesel Engine Plant, Sichuan Hongyan Machinery Plant, Wuxi Diesel Engine Plant, Yiwu Diesel Engine Plant, and Kangda Power Equipments Plant. A small number of self-made systems with mixed quality are also used by plants.

By 2008, 120 biogas systems had been introduced with total installed capacity of 50MW, or 28.9% of total installation in China, of which 30 units, 18MW, were deployed in rural areas, and 80 units, 32MW were installed for urban utilities.

Current livestock biogas generation projects are of single capacity between 80 and 200kW, mostly off-grid. The generated electricity is for self-use of farms. There is already mature product for 500 kW biogas internal combustion generation units but is seldom used because of small size of biogas projects. Only three grid-connected livestock biogas projects have been developed in China: Inner Mongolia Mengniu Group (1MW), Beijing Deqingyuan (2MW), and Shandong Minhe (3MW). All the three projects are connected to grid.

5.8 Recommendations

5.8.1 Conduct National Biomass Resource Survey

It is recommended that NDRC, in conjunction with other authorities in agriculture, forestry, meteorology, land resources, environmental protection and statistical ministries and bureaus to produce both technical procedures and assessment methodology for the national biomass resource potential survey. During the survey, data on availability and distribution of biomass resources and marginal land uses, as well as biomass technology status and potentials will be collected and inserted into a national biomass resource database. The survey and database should be completed in the coming two years.

5.8.2 Making Plan for Energizing Biomass Resources

Based on the resource survey and assessment, NDRC will organize activities of making a dedicated national plan for biomass energy development. Regional plans at provincial level will also be developed for biomass energy deployment, under the guidance of the national planning. The planning activities shall follow the requirement specified in *the State Council's Decisions on Strengthening National Economy and Social Development Planning Activities (State Council [2005] No. 33)*. The NDRC coordinate the planning. In planning activities, the rural energy deployment principle of "local adaptation, hybrid of multiple energy sources, comprehensive utilization, and cost-effectiveness" has been enhanced. Priorities will be given to the demand of organic fertilizers, livestock feedstuff, and domestic fuel. Biomass resources will be arranged for paper making and artificial board production in a unified manner. On the basis of flexibility and reasonable layout, great efforts should be made to develop the technology for energizing biomass.

5.8.3 Supporting Suitable Biomass Generation Technologies in the Principle of Local Adaptability

Biomass resources are dispersed with varied local conditions. Therefore, R&D of diversified biomass power generation technologies should be encouraged in order to establish a biomass power generation technical system which has the flexibility to adapt to different conditions and environments.

5.8.4 Making Standards and Strengthening Regulatory Regime

It is recommended that Standardization Administration and the General Administration of Quality Regulation, Inspection, and Quarantine (AQSIQ) work together with relevant departments to develop the technical standards, equipment test and certification system for biomass power. The technical codes and specifications should be prepared by NDRC in conjunction with other relevant authorities.

5.8.5 Accelerating Expenditure in R&D

It is recommended to increase the current spending on R&D in biomass energizing technologies, to support the improvement of capacity to design and manufacture critical and auxiliary energizing equipments, and to stimulate R&D in equipments related to biomass fuel collection, processing, storage, and transport.

5.8.6 Establishing Specialized Biomass Businesses

Different types of investors, including private investors, are encouraged to invest in biomass industry and to establish specialized biomass businesses so that the current situation of low-level redundant biomass power projects built by waste producers can be changed in order to improve technologies of waste-to-energy projects.

Specialized operators of biomass power generation projects are encouraged to improve management of biomass projects for better revenue and social benefits. Cooperation between strong biomass equipment manufacturers should be supported to develop large and super manufacturing businesses in China.

Technical research and development groups on biomass technologies are encouraged to incorporate industry, academy, research, and design. Investment in biomass technology development and manufacturing will be strengthened to improve overall capacity building in equipment manufacturing.

5.8.7 Expanding Financing Channels for Biomass Power Projects

Financing and loan interest rate incentives will be provided to businesses in the area of biomass energy. Those banks take the responsibility of guiding industry should give priority to biomass energy projects in financing.

5.8.8 Clarifying Tariff and Enhancing Market Competitiveness of Biomass Energy Projects

Due to the dispersion and high collection cost of biomass, the price subsidy and tax incentive policy for biomass energy should be implemented in the principle of combining governmental guidance and market rules.

5.9 Best Case: National Bio Energy Co. Ltd.

The National Bio Energy Co., Ltd. (NBE) is a specialized biomass energy development company. In addition to investing in biomass power projects, the company has extended its production chain to downstream to engage in the production and processing of biomass fuel and ash recycling.

Established in July 2005 with registered capital of RMB2 billion, NBE is invested by Longji Electric Power Co. Ltd (RMB1.5 billion, 75%) and State Grid Shenzhen Energy Development (Group) Co. Ltd. (RMB500 million Yuan, 25%).

By the end of 2008, NBE had obtained licenses of 40 biomass projects in China's Shandong, Hebei, Henan, Jiangsu, Heilongjiang, Jilin, Liaoning, Inner Mongolia, Xinjiang, Hubei, Anhui, and Shannxi provinces. Currently 16 projects have been completed with installed capacity of 37.2MW.

The company actively participates in the CDM projects and made substantial progress. In 2007, NBE won the title of top 50 China Green Energy Companies and be nominated for the International Environment Award.

NBE uses imported Danish BWE technology for localized biomass direct combustion boilers (at Jinan Boiler Factory). The boilers are featured by high temperature and pressure, natural circulation, all-steel frame, wood feedstock, vibrating grate, and bubbling. The products are designed by learning from international best practices in boiler design and operation, biomass fuel characteristics, and combustion features. Its boilers are advanced in steam parameters, and thermal efficiency, layout of combustion structure, heat bearing materials, corrosion resistance, and manufacturing precision.

5.10 Biomass Power Policies and Regulations

5.10.1 Provisions in the *RE Law*

1. Article 2 specifies that "renewable energy in this Law refers to non-fossil energy sources of wind, solar, hydro, biomass, geothermal, and ocean energy, etc." Biomass energy is specifically defined in the supplementary provisions as "energy converted from natural plants, rejecta as well as urban and rural organic waste." "Plants" include agricultural residues (straws and nuts/husks) and forestry wastes (forest residues and wood processing wastes); "rejecta" includes the livestock waste for biogas generation; and "urban and rural organic wastes" include municipal waste, industrial organic waste, sewage, and industrial organic water sources. In addition, biomass also

includes energy plantations called energy crops.

2. Article 11 provides that “standardization authorities of the State Council shall set and publicize technical standard for renewable energy electric power and the technical standards for relevant renewable technology and products for which technical requirements need to be standardized at the national level.” Industrial standards are necessary to maintain a biomass industry. Since biomass energy industry is just started, the industry has not been well developed, nor required standards. Efforts relevant to the standardization activities are undertaken along with the RE Law implementation.

3. Article 13 points out that “the government encourages and supports various types of grid-connected renewable power generation.” As the grid-connected generation will become a development trend, biomass power generation will be strongly supported by the RE Law.

4. Article 14 provides that “grid businesses shall enter into grid connection agreements with renewable power producers that legally obtained administrative license or for which filing has been made, and purchase all the grid-connected power produced with renewable energy sources within the coverage of their power grid, and provides grid-connection service for the generation of power with renewable energy.” The size of biomass power is small so it can be invested by local and private businesses. Therefore, it may encounter difficulty in grid connection. The grid businesses must “buy the grid-connected power produced with renewable energy within the coverage of their power grid, and provide grid-connection service for the generation of power with renewable energy.” This article provides legal guarantee for biomass power sales.

5. Article 15 provides that “the government supports the buildings of independent renewable power systems in areas not covered by the power grid to provide power service for local production and living.” By this article, independent biomass power generation projects in no grid access areas shall be encouraged, which include self-supporting power plant from waste biomass resources.

6. Article 19 provides that “grid power price of renewable energy power generation projects shall be determined by the price authorities of the State Council in the principle of being beneficial to the development and utilization of renewable energy and being economical and reasonable, where timely adjustment shall be made on the basis of the development of technology for the development and utilization of renewable energy. The price for grid-connected power shall be publicized.” This means different pricing principles for renewable energy tariffs shall be implemented for biomass, solar, and wind power etc.

7. Article 20 provides that “the excess between the expenses that power grid businesses purchase renewable power on the basis of the price determined in Article 19 hereof and the expenses incurred in the purchase of average power price generated with conventional energy shall be shared in the selling price. Price authorities of the State Council shall prepare specific methods.” Because of the higher cost of renewable power compared with conventional generation and its social benefits for environment, it should enjoy higher tariff. However, during the business

operation, it is not reasonable to ask renewable power companies to bear the high cost of social benefits. This article defines the cost sharing mechanism. That is, the additional cost in renewable production will be shared by all electricity users because of its contribution to environmental benefits.

8. Article 21 provides that “grid connection expenses paid by grid businesses for the purchase of renewable power and other reasonable expenses may be included into the power transmission cost of grid businesses and retrieved from the selling price.”

9. Article 22 provides that “for the selling price of power generated from independent renewable energy power system invested or subsidized by the government, classified selling price of the same area shall be adopted, and the excess between its reasonable operation and management expenses, and the selling price shall be shared on the basis of the method as specified in Article 20 hereof.”

10. Article 29 provides that “if the power grid businesses breach Article 14 hereof and fail to purchase renewable power in full, which results in economic loss to the renewable power generation businesses, such power grid businesses shall be liable for compensation, and the national power supervisory institutions shall order them to make correction within a stipulated period of time; in case of refusal to make correction, a fine of less than the economic loss of the renewable power generation businesses shall be imposed.” Compared to grid companies, renewable power producer businesses are ‘vulnerable groups’. This article provides a legal support for renewable energy producers and embodies national support for the renewable power sector in China.

5.10.2 Some Regulations Defined in the “Medium- and Long-Term Development Plan for Renewable Energy in China”

1. In the Plan’s first article concerning development objectives and targets, it is indicated that “by fully utilizing, to the extent possible, technologically mature and economically feasible renewable energy sources, such as hydropower, biogas, solar thermal, and geothermal, as well as by promoting the development of the wind power, biomass power, and solar PV industries, by 2010, China will aim to raise the share of renewable energy in total primary energy consumption to 10%. By 2020, it will aim to raise this share to 15%.”

2. In terms of “priority development sectors”, it provides that “based on analysis of the resource potential, technological situation, and market demand for all types of renewable energy, the priority sectors for renewable energy development in China up to 2010 and 2020 will include biomass power generation, biogas, biomass pellets (used directly as fuel), and liquid biofuels. By 2010, the installed capacity of biomass power will reach 5.5 GW; the annual use of biomass pellets for fuel will reach 1 Mt…”

3. Concerning agro and forestry biomass power generation priorities, it requires that “Biomass power from agro and forestry biomass will be developed at China’s main grain production areas.

By 2010, the installed capacity of biomass power based on agricultural and forestry wastes and energy crops plantations (bagasse included) will be 4 GW. By 2020, the installed capacity of biomass power based on agricultural and forestry wastes and energy crops plantations (bagasse included) will be 24 GW. Energy plantations will be grown in marginal areas (including barren mountains, barren land, and sandy areas suitable to forestation) to supply feedstock for agriculture and forestry based biomass power generation."

4. In terms of developing biomass power capacity from livestock wastes, industrial organic waste water and municipal solid waste, it requires that "by 2010, 4,700 large-scale biogas projects on livestock farms and 1,600 biogas projects utilizing industrial organic effluent will be built with a total annual production of 4 b m^3 biogas and total installed capacity of 1 GW. By 2020, 10,000 large-scale biogas projects on livestock farms and 6,000 biogas projects utilizing industrial organic effluent will be built with a total annual production of 14 b m^3 biogas and total installed capacity of 3 GW."

5.10.3 Management Measures for Power Generation from Renewable Energy Sources

All provisions concerning renewable power generation, including feed-in tariff and cost sharing, cover biomass power.

6 Liquid Biofuels

6.1 Introduction

Biomass energy is always the major energy resource for rural area of China. Usually, the biomass is used mainly for cooking and heating, with traditional low-efficiency and high-consumption utilization methods. Because of the large population, short resources, and low-level technologies, biomass utilization has caused problems such as waste of resources, destruction of environment, and deterioration of ecology. In recent 30 years, technologies for biomass utilization have been developing rapidly. For liquid biofuels, the industry development began at the beginning of the 21st century. Historically, biomass energy has been used in transportation in the Second World War, while gas fuel from wood pyrolysis was used to substitute fossil fuels.

Oil crisis in 1970s convulsed vehicle's gasoline tanks in China. In the end of 1970s, facing the austere situation of energy and environment, China started the development and utilization of renewable energy resources. At the beginning of the 21st century, fuel ethanol made from food crops was used in partial areas of China. With the problems of energy and food safety stood out in the world, new projects of fuel ethanol from food crops were banned in China in 2007. Since then, China began to develop fuel ethanol from non-food crops and bio-diesel without competition with edible oil. By the end of 2007, the production capacity of fuel ethanol from food crops was 1.5 Mt, and from non-food crops 0.3 Mt. The production of bio-diesel was about 0.3 Mt per year. Fuel ethanol is used in 9 provinces, including entire area of Heilongjiang, Jilin, Liaoning, Henan, and Anhui, and part area of Hebei, Shandong, Jiangsu, and Hubei.

Chinese government states that due to the restriction by food crop production and arable land resources, the government will encourage the production of fuel ethanol from non-food crops such as sweet sorghum and cassava, and the production of bio-diesel from oil plants such as jatropha, Pistachio chinesis, and cotton seed.

At present, the production capacity of liquid fuels from non-food crops in China is about 0.5 Mt. China has made a national plan for liquid biofuel. According to the plan, by 2010, the production of fuel ethanol from non-food crops will reach 2Mt and bio-diesel production from oil plants will reach 0.2Mt per year.

6.2 The Basic Principle of Developing Liquid BIofuels

The principle of developing liquid biofuels of Chinese government indicates “do not compete with people for grain, do not compete with grain for land, and do not compete with agriculture and forestry for water.” The liquid biofuels should be developed in an appropriate way.

6.3 Technological Support and Industry Operation

Chinese Government gives priority to the second-generation bio-ethanol made from cellulose, and the planting of high-productivity oil crops. Generally speaking, the R&D of biofuel technology in China is rather undeveloped. The State supports the following projects:

- In August 2007, a 3,000 tons per annum (tpa) cellulose ethanol project was founded in Henan Tianguan Group, which is the first thousand-ton cellulose ethanol production line in China.

- COFCO has succeeded in commissioning the 500 tpa cellulose ethanol project in Heilongjiang Province. It is the first facility that adopts continuous steam explosion technology to convert cellulose into ethanol. Enzyme preparation, the key of the ethanol production from cellulose material, was developed by COFCO and Novozymes of Denmark. COFCO has established new fuel production bases in northeast, north and south of China.

- Xinjiang launched a bio-gasoline production project. Xinjiang Santai Liquor Corp. is building a straw-to-ethanol project with annual production of 100,000 t and investment of RMB280 million, to be completed in 2009. Shache County, in southern Xinjiang, and Zhejian Haoqi Biomass New Energy Technology Ltd. invest RMB1.26 billion to develop a project using sweet sorghum to make ethanol, with annual capacity of 300,000 t.

The total capacity of bio-diesel production in China is above 3Mt. According to incomplete statistics, there are 26 bio-diesel businesses with capacity of more than 10,000 tpa, of which 13 companies have capacity below 50,000 tpa, 7 businesses have capacity 50,000-100,000 tpa, and 6 businesses have capacity over 100,000 tpa. Assuming the price RMB7,000/t, 13 companies have revenue below RMB300 million, 12 companies RMB300-1000 million, and only 1 company has revenue over RMB1 billion. Apart from existing capacity, there are a number of large scale bio-diesel program that under construction, with a total capacity of 3Mt.

Although the production capacity shows that the bio-diesel industry in China is scaling up, the real production in 2007 was 300,000 t, 10% of the full capacity due to shortage of raw material and high prices. Currently, most of factories in China stop running partially or entirely. The industry development is facing big challenge.

The barriers to bio-diesel industry development in China are: 1) constrains from feedstock; 2) lack of marketing channel; 3) lack of incentive policy.

7 Biogas

7.1 Introduction

The use of biogas in China has a history of several decades. The number of households that use biogas was 6000 in 1970 and 7.23 million in 1980. The number was 4.53 million at the end of 1986. During the 8th FYP period, the average annual increase of households that use biogas is 360,000 and during the Ninth FYP period 750,000. By the end of 2000, there were 9.8 million rural households using biogas pools. The biogas entered the healthy, steady and rapid development stage during the 10th FYP period. Since 2003, rural biogas development has been included in the projects supported by treasury bonds. The central government allocated over RMB1 billion biogas projects. With the strong push by government policies, the household biogas has seen a large-scale trial-production and formed an industry. Since 2000, the large and medium-sized biogas projects of livestock farm, food processing, brewery, urban sewage treatment plant also began to develop. By the end of 2008, the households that use biogas added up to 32 million; the annual output of biogas was 12.4 b m^3; and the biogas projects of livestock farm were 28,300, with the total pool volume of 3.03 m m^3 and the annual output of 379 m m^3.

With progress of biogas technology, the household biogas systems and components have reached standardized production and specialized practice. Biogas technology services are developed in most areas, with a strong technical service capability. Technology for large and medium-sized biogas projects is mature with established professional design and construction teams. There is a comprehensive service system and the condition for large-scale development.

The feedstock resources of biogas production in China are very rich. Besides the livestock and poultry rejecta, straw and organic wastes in rural areas, there are organic wastes produced by agro-processing and bio-energy processing, as well as the more and more urban organic wastes. Biogas is one of the four priority renewable energy programs in China. The focus of recent development is to expand household biogas in rural areas, especially the combination of biogas technology and agricultural production, to develop concentrated biogas supply based on the large-scale livestock farms and industrial waste water. The utilization goal of biogas by 2010 and 2020 are 19b m^3 and 44b m^3respectively.

7.2 Resources / Economic Potential

1. Total volume of livestock and poultry rejecta and biogas resources

Table 12 Potential Analysis of Biogas Resources in Livestock and Poultry Industry of China (2007)

	Pig	**Cattle**	**Chicken**	**Total**
Stock （thousand）	439895*	105948*	4511613**	
Daily rejecta (kg / day)	2	20	0.12	
Annual rejecta (100 Mt)	3.21	7.73	1.98	12.92
Collection coefficient	1	0.6	0.6	
Dry matter content (%)	20	18	36	
Biogas production (m^3 / kg dry matter)	0.3	0.2	0.36	
Resource potential for biogas production (100 M m^3)	192.67	167.06	153.66	513.39

* Data from the National Bureau of Statistics ** data from FAO

According to the number of pigs, cattles and chicken in 2007, the livestock and poultry rejecta of livestock and poultry industry (only including pig, cattle and chicken) was nearly 1.3 Gt throughout the year, of which, the rejecta of pig, cattle, chicken was 321 Mt, 773 Mt and 198 Mt respectively. The actual total volume of sewage was 20 Gt plus the wash water used by large-scale production, which can produce biogas of 51.3 b m^3 based on technical potential analysis.

2. The amount of industrial organic wastewater resources that can be transformed into biogas

In 2002, the industrial wastewater was about 3 b m^3 (without treatment)[1], of which the industrial organic wastewater was about nearly 85%. Currently, taking the volume of industrial organic wastewater as 2.52 Gt/year and that of waste residue as 73 Mt/year, 10.675 b m^3 of biogas can be produced per annual through anaerobic digestion, of which 9.335b m^3 from industrial organic wastewater and 0.74 b m^3 from waste residue respectively.

Taking the development of national economy into account, the gross industrial output value of China in 2007 was 2.3 times as much as in 2002, while the emission of industrial organic waste water (waste residue) was 1.2 times as much as in 2002. It can produce 12.81b m^3 biogas in 2007, if we estimate it on the basis that the volume of biogas resources was 1.2 times as much as in 2002.

3. The volume of straw resources that can be transformed into biogas

The straw resources are very rich in China, and the annual output of straw is about 650 Mt. But more than 50% are directly burned or abandoned, so the overall utilization efficiency is low. At present, the biogas production technique based on the fermentation of straw as a feedstock (straw bio-gasification technology) has made a breakthrough. After 3-7 days pre-treatment with addition of

[1] According to the findings of the NDRC / GEF / UNDP project –Capacity Building Strategy for the Rapid Commercialization of Renewable Energy in China.

biological agents, straw can be put into biogas pool. The biogas produced is at the same level as rejecta. The technology has been deployed in more than 100 villages across the country. For the farmers who have built biogas pools, even if they no longer engage in farming, the biogas can be used too. For the farmers who do not engaged in animal farming, they can also build biogas facilities, thereby greatly expanding the development space of rural biogas.

7.3 Additional Installation Capacity in 2007 and 2008 and Gap from 2010 Goal

The biogas developed rapidly in 2007-2008. The new rural biogas users in 2007 were 4.82 million households and the accumulated biogas users were nearly 26.5 million households with the annual output of biogas 10.2b m^3, an increase of 18.02 million households compared to 8.48 million in 2000, an average annual growth rate of 17.7%. In 2008, there were more than 5.5 million newly-added households and the accumulated number was nearly 32 million with the annual output of biogas 12.4b m^3. But there is still a certain gap from the goal of 40 million in 2010.

The biogas projects based on livestock and poultry farms developed rapidly in 2007-2008. In 2007, the number of livestock and poultry farm biogas projects newly constructed was about 9,763; the number of rejected projects was 652; the available number at the end of the year was 26,600 with the total pool volume was 2.85m m^3 and the annual biogas production of 356m m^3, of which, the number of large and medium-sized biogas projects was 8,576 with the total pool volume of 1.14m m^3 and the annual biogas production of 291m m^3. The year 2008 saw 1,716 new biogas projects linking livestock and poultry farm and household, and a total of 28,300 biogas projects based on livestock and poultry farms with the total pool volume of 3.03 m m^3 and the annual biogas production of 379 m m^3, significantly beyond the objective of 4,700 large and medium-sized farm biogas projects in 2010.

In 2007, the number of new industrial biogas projects was 57, and the number of rejected projects was 44, the available number by the end of the year was 285 with the total volume of 490,000 m^3 and the annual production of biogas 133m m^3.

7.4 Existing Policies, Measures and Local Regulations

1. State laws and regulations on the development of biogas

The strategic position and path of renewable energy were determined by the form of law clearly in the *ReLaw* in 2005. The law encourages and supports the development and utilization of renewable energy in rural areas, and promotes the industrial development of biogas projects. Among them, the Article 18 regulates that "the state encourages and supports the development and utilization of renewable energy in rural areas. According to the local economic and social development, the ecological protection and comprehensive management of health and other actual situation, the energy management sectors of local people's governments above the county level jointly with other organizations concerned develop the program of renewable energy in rural areas, popularize the application of biomass resources transformation, solar home system, small wind power, small hydro power and other technologies. People's governments above the county level should provide financial support for the use of renewable energy projects in rural areas."

Article 7 of the *Energy Conservation Law of the People's Republic of China (2007 Amendment)* provides: "the state encourages and supports the development and utilization of new energy, renewable energy”. Article 59 of the law also stipulates that the State encourages and supports strongly the development of biogas in rural areas.

Article 52 of the *Ordinance of Returning Farmland to Forest* states that "the local people's governments should strengthen the rural energy buildings, such as biogas, small hydropower, solar energy as well as wind energy, and settle the demand of returning farmland to forest in accordance with the actual situation."

2. State policies for the development of biogas

The Chinese Government attaches great importance to the construction of rural biogas projects, takes the construction of biogas in rural areas as an important means of addressing the environmental pollution, the development of biomass energy in rural areas, and building the new socialist countryside, issues a series of policies of encouragement and support. The *Opinions of CPC Central Committee and the State Council on Agriculture and Rural Work ([2003] 3)* points out that "the rural small and medium-sized infrastructure construction has a significant effect on increasing directly the income of the farmers, improving production and living conditions in rural areas. It is necessary to accelerate the development. "The State agricultural capital construction investment and agriculture support funds should continue to focus on the following “six small projects” to expand the investment scale and enrich the contents of construction: water-saving irrigation, drinking water, rural roads, rural biogas, rural hydropower, as well as pasture fence. We should focus on the areas of returning farmland to forest to support the development of rural biogas".

In order to strengthen the management of State treasury bonds for rural biogas projects, the central government issued *Management Methods Concerning State Treasury Bonds for Rural Biogas Projects* in December 2003. The subsidy standards of household biogas pool by central government are as follows: In northwest and northeast, RMB1,200 subsidy per household; in southwest, RMB1,000 per household; and other regions, RMB800 per household.

"Opinions of CPC Central Committee and the State Council on Policies of Increasing Farmers’ Income” ([2004] 1) points out that the "six small projects" play an active role for improving production and living conditions of farmers, increasing the employment and the income of farmers. It is necessary to further increase the scale of investment, to enrich the contents of construction and to expand the scope of construction.

"Opinions of CPC Central Committee and the State Council on Further Strengthening Rural Work to Improve Comprehensive Agricultural Production Capacity " ([2005] 1) requests "to accelerate the pace of energy development in rural areas, continue to push forward the construction of rural biogas."

"Notice of the State Council on the Recent Priorities of Building a Resource-Saving Society " ([2005] 21) requires" to develop household biogas pools and large and medium-sized livestock and poultry farm biogas projects in rural areas, and to promote straw and coal saving stove."

The Fifth Plenary Session of the Sixteenth Central Committee of the Communist Part of China requires "to promote biogas in rural areas vigorously, to develop clean energy in rural areas positively."

"Opinions of CPC Central Committee and the State Council on Promoting the Construction of New Socialist Rural Areas" ([2006] 1) points out: to speed up the pace of energy development in rural areas, to promote biogas actively in the appropriate region, to increase the scale of investment in rural biogas construction significantly, to speed up the popularization of household biogas, to support large and medium-sized farm biogas in the appropriate regions, and to take the construction of biogas pools as a major factor to change the stockyard, lavatory and kitchen in rural areas.

The *Opinions on Active Development of Modern Agriculture and Solid Advancement of New Socialist Rural Areas Construction ([2007] 1)* issued in 2007 points out: … speed up the development of clean energy in rural areas, continue to increase the investment of biogas construction in rural areas…. In order to implement this document, to strengthen the construction and management of biogas in rural areas, MOA issued the *Opinions of Ministry of Agriculture and National Development and Reform Commission on Further Strengthening the Management of Rural Biogas Construction* in August 2007.

3. State planning for the development of biogas

The Fifth Plenary Session of the Sixteenth Central Committee of the Communist Part of China indicates: "to promote biogas in rural areas vigorously, to develop clean energy in rural areas positively." In order to speed up the development of rural biogas, to promote the construction of new socialist countryside, MOA issued the *National Rural Biogas Projects Construction Plan (2006-2010)* in March 2007, which includes the following contents, targets, geographical distribution and scale in three aspects: household biogas in rural areas, large and medium-sized biogas projects in farms with mass production, and technical support and service system. According to the planning, the number of new rural biogas households in 2006-2010 is 23 million, with a total investment of RMB40.065 billion of which RMB12.5 billion is from the central government. By the end of 2010, the number of rural biogas users will be about 40 million households, accounting for 30 % of appropriate rural households. In 2006-2010, the number of new large and medium-sized biogas projects based on the existing scale farms is about 4,000, and by the end of 2010, the number of large and medium-sized biogas projects in scale farms will be about 4,700, accounting for about 39 % of the total number of the existing large and medium-sized livestock and poultry farms.

To support the implementation of *the ReLaw*, MOA released the *Agricultural Biomass Energy Industry Development Plan (2007-2015)* in May 2007, which put forward the strategic objectives, development priorities and the industrial layout of these three fields, rural biogas, rural straw resource use and energy crops in 2010-2015. By 2010, the total number of rural households with biogas will be 40 million, accounting for about 30 % of appropriate households, producing biogas about 15.5 bcm; by 2015, the total number of rural households with biogas will be 60 million, producing biogas about 23.3 bcm and promoting the industry of rural biogas. By 2010, the number of new biogas projects in scale farms will be 4,000, with new annual addition of biogas 336 million CUM; by 2015, the number of biogas projects in scale farms will be 8,000, with annual production of biogas 670 million CUM.

According to Article 7 of *the ReLaw*, NDRC issued the *Medium and Long Term Plan of Renewable Energy Development* that defines the total target of medium and long term plan of renewable energy development. The plan clearly defines that, by 2010, the volume of biogas use reaches 19 bcm. There are about 40 million households (about 160 million people) using biogas as living fuel, with the annual consumption of 15 bcm. By 2020, the volume of annual biogas use reaches 44 bcm. There are about 40 million households (about 300 million people) using biogas as living fuel, with the annual consumption of 30 bcm. By 2010, the number of new scale livestock and poultry farms biogas projects is 4,700; the number of industrial waste water biogas projects is 1,600; and the production of large and medium-sized biogas projects is about 4 bcm. By 2020, the number of large livestock and poultry farms biogas projects is 10,000; the number of industrial waste water biogas projects is 6,000; and the annual production of biogas is about 14 bcm.

According to the overall requirements of Medium and Long Term Plan of Renewable Energy Development and the latest progress of the development of renewable energy in China, NDRC adjusted the development objectives and priorities in the "Eleventh Five-Year" period and issued "The Eleventh Five-Year-Plan of Renewable Energy Development" in August 2008, further defining that by 2010, the annual production of biogas reaches 19 bcm based on which the number of biogas households reaches 40 million, the production of rural biogas reaches 15 bcm, and the number of scale farm biogas projects reaches 4,700.

4. Local biogas ordinances and plans

In accordance with national policies, laws, regulations and planning, local governments develop the local regulations, policies or management regulations in line with the local actual conditions, to make up for the shortage of national policies, regulations and planning. For example, Tibet Autonomous Region issued *Rural Biogas Development Plan of Tibet Autonomous Region (2006-2010)*; Zhejiang Province issued *Promotion Measures for the Development and Utilization of Biogas in Zhejiang Province* in February 2005; Hunan Province *issued Ordinance on Renewable Energy in Rural Areas of Hunan Province* in 2006; Shanghai, Yunnan and other provinces issued *Renewable Energy Development Ordinance*. According to official data, there are more than 1/3 provinces in China having issued the management regulations of biogas in rural areas.

7.5 Investment Dynamics and Industrial Trend

7.5.1 Investment Dynamics

Investment by central government

Major investment from the central government has been put in the development of rural household biogas and large and medium-sized livestock/poultry farm biogas projects. During the Ninth Five-Year Plan period, the nation invested RMB554, 100 in gas projects. During the Tenth Five-Year Plan period, the investment has been further improved with a total investment of RMB3.534 billion for rural biogas development. In 2003, the program of state treasury bonds for rural biogas projects was launched. The program involved 24 provinces, 540 counties, more than 6000 villages, and 1.03 million households. In 2004 and 2005 rural biogas development funds were RMB1 billion. In 2006 and 2007, the State arranged RMB2.5 billion for rural biogas development projects, more than 1.5-fold increase compared to 2005. In 2008, the State invested nearly RMB2.7 billion for the development of rural biogas.

Table 13 Central Government Investment in Biogas Development in Rural Areas (2001-2008)

Year	Total: Central Government Investment	Rural Household Biogas		Large and Medium-sized Biogas Project	
	RMB (million)	No. of households	RMB (million)	Number	RMB (million)
2001	130	165424	123.70	17	6.8
2002	309.9	286333	286.45	49	23.45
2003	1030	1033248	1016.4	24	13.6
2004	1032.5	1044279	1012.5	20	20
2005	1029.8	1046381	1012.5	10	17.3
2006	2500	2554029	2455.06	-	44.94
2007	2328.75	2377271	2303.77	882	24.98
2008	2646	2524092	2595.91	1716	50.09

Source: Data for 2001-2005 are from the National Rural Biogas Development Plan (2006-2010). Data for 2006-2008 are from MOA's approvals for the provinces, regions, and cities in rural biogas projects financed by State bonds.

International cooperation

In addition to the central and local governmental financial investment, international aid agencies in China also invest in biogas projects and support biogas policy, technology, management research and demonstration projects.

Since 1990, the Japan Kamiuchi China Agricultural Aid Program has invested JPY900 million in biogas projects in China, including the Kamiuchi-Sichuan Eco-home Program started in 2003.

The China Rural Energy/Ecology Development Program funded by loan from Asian Development Bank (ADB) was launched in 2003, using ADB loan of USD33.12 million and the Global Environment Facility (GEF) grant of USD6.361 million, with a construction period of 5 years and completed by the end of 2008.

The Program of Promoting Comprehensive Development and Application of Renewable Energy in the Rural Area of Western China funded by the Dutch Government started in January 2003 and ended in June 2007. The Dutch government funded a total of EUR5.3 million in Gansu, Sichuan, Hunan, and Hubei provinces to promote the use of renewable energy sources (biogas, solar, wind, etc.) to help farmers to improve the quality of life.

In addition, the World Bank's eco-home program also funded rural biogas project.

7.5.2 Development Trend

Investment in large and medium-sized biogas projects is enhanced. Although in 2003 the state began to strongly support biogas projects, the target was still mainly the rural household biogas, lack of enough efforts for large and medium-sized investment. From 2003 to 2005, large and medium-sized biogas investments accounted for about 2% of total investment. As the State enhances pollution control in livestock and poultry farming and issues biogas development plan, it has begun to increase investment in large and medium-sized biogas projects. In recent years, the State invests over RMB1 billion annually in livestock and poultry farms to support the large and medium-sized biogas projects. With the scale development of farms, biogas projects will gradually develop in scale and State investment will also gradually increase.

7.6 R&D

After many years of research and development, biogas technology in China is becoming mature. The key technology has achieved breakthrough. Technical support capacity is stronger. The standard of pool types has been developed to adapt to different climates, feedstock, and application conditions. Pools under construction use cast-in-place concrete construction technology, and are built by trained technical staff to ensure that the biogas-generating pools have more than 15 years of lifetime. Some pools in use have already served for more than 20 years. In the management, a variety of convenient and practical devices and tools have been developed to solve the problem of feedstock exit, so that the biogas management becomes easier. The use of straw as feedstock to produce biogas has seen breakthrough. The process is being demonstrated around the country. Test results show good adaptability. This expands biogas feedstock sources and provides the possibility for non-pig farmers to build biogas pools and pig farmers who no longer feed pigs to continue the use of biogas. As of the end of 2007, household straw biogas has grown to 55,000 sites, adding 50,083 sites in that year, compared to 4397 sites in 2006. As for large and medium-sized biogas facility engineering, through independent R&D combining importation, the engineering technology becomes more mature and the fermentation process has reached international advanced level.

In recent years, the State, through technological breakthrough programs, 863 Program, 973 Program and commercialization plans, has improved the production process and equipment technology in large and medium-sized biogas projects, to develop established capacity in biogas equipment and engineering. Among them, the Scheme of Low-temperature Biogas Production and Commercialized Utilization Technology under the 863 Program was kickstarted in July 2008. The project is targeted at low-temperature region in northern China and low efficiency of biogas production, and intends to use genetic engineering and metabolic engineering, high-yielding strains of different advantages and features of the optimized combination to achieve a balanced and efficient production of biogas and commercialization.

In December 2008, the new high-performance large-scale biogas project, as a key program supported by the Start in the "Eleventh Five-Year" period, was launched. The project aims at addressing the key issues and technical bottlenecks in large-scale production of biogas, such as geographical constraints, single choice of feedstock, backward fermentation technology, low efficiency of gas production, poor equipment compatibility, rough manner of using biogas, liquid and residue. Work has been done to carry whole-process and multi-tier RD&D, shaping a series of major integrated biogas fermentation technology and complete sets of equipment and products to enhance the technology and equipment competence as well as comprehensive benefits of China's large-scale biogas projects. The project also intends to change the status quo in large and medium-sized biogas project, to guide and promote the overall level of large-scale biogas project and corporate competitiveness, to foster a number of research institutions for advanced biogas technology and equipment, and to help grow brands and industry leaders, providing strong technological support for large-scale development and utilization of biogas energy.

7.7 Local Practice: Best Case in Hunan Province

As one of the major agricultural provinces, Hunan biogas development in rural areas has been at the forefront of the country. Hunan has certain favorable conditions for biogas development and its experience is of the representative in the country. Local government strongly supports the development of biogas. The *Ordinance on Renewable Energy in Rural Areas of Hunan Province* released in November 2005 clearly demonstrates the Government's strong support for biogas. The *Hunan Eleventh Five-Year Circular Economy Development Plan* clearly defines development goals by 2010. During the "Eleventh Five-Year" period, Hunan will build 1,500,000 rural household biogas pools and 5000 large and medium-sized biogas sites in livestock and poultry farms. In recent years, the Government has increased efforts to promote biogas. In poverty-alleviating villages designated by the government and new village demonstration sites, farmers are guided and supported to develop biogas. By end of 2007, Hunan has 1.77 million household biogas pools, with the total volume of about 17 million cubic meters and an annual output of 830 million cubic meters biogas with success rate of 100 % and the utilization rate of over 98%. Biogas projects have developed from scattered ones to large coverage. In the province, 11% of rural households have been connected to biogas. The number is 60 % in demonstration towns and over 90 % in demonstration villages.

8 Small Hydro Power

8.1 Introduction

Small hydro power (SHP) is an important renewable energy source in China. Usually, in China SHP is integrated with local grid. The capacity of SHP varies by location and time. Some countries and organizations even prescribe the corresponding water heads and diameter range. In China, the capacity boundary of SHP is also related to rural economic development and electricity consumption.

Therefore, China often calls SHP as rural hydropower. In China, Class IV and Class V hydropower projects are classified as small ones, habitually referred to as Small-1 and Small-2 hydropower stations with the capacity limits of 50 MW and 10 MW respectively.

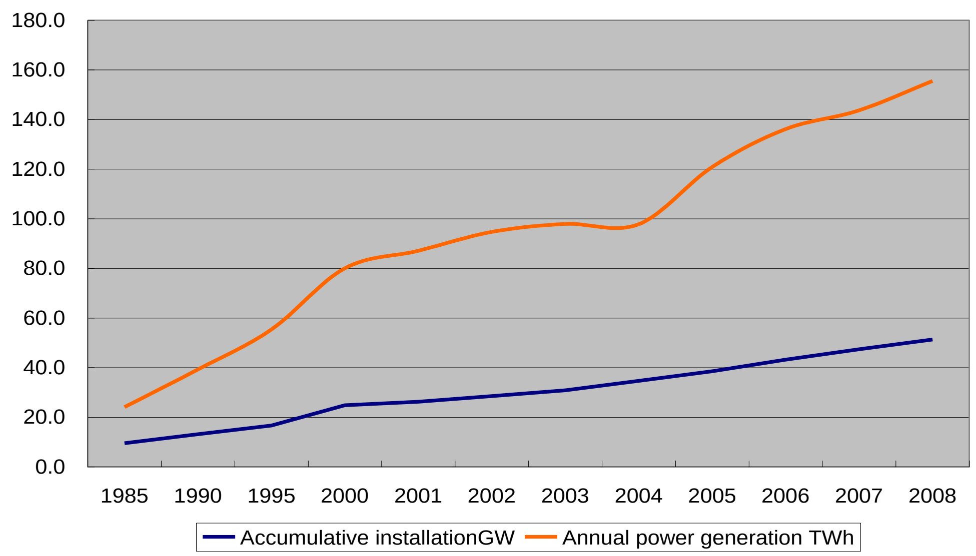
SHP development in China is very fast for many reasons: small size, short construction period, small investment in infrastructures, limited impacts on immigration, environment and ecology, short distance to users and low cost of transmission lines and loss. By the end of 2007, China had built 45,317 SHP stations with total installed capacity of 47,389 MW, about 32 percent of total hydropower capacity of the year in China and approximately the sum of SHP capacity of the rest of world.

8.2 SHP Resources Distribution and Development

The water reserves of a river refers to the average output of hydropower resources derived from calculating an average flow of the river over the years and the falls section by section. A nation's water reserves are related to its land area, river runoff and elevation of the terrain. The exploitable hydropower resources refer to installed capacity and an annual generation capacity of hydropower stations at all levels identified in representative cascading development programs of every river by surveying and planning.

Given its broad landscape, China has many rivers with abundant run-off and waterfalls with tremendous hydropower potential. Apart from large rivers, their tributaries with abundant SHP potential are there all over the country. The total developable capacity of SHP potential is estimated at 128 GW, and relevant annual electricity production could be 350-400TWh. There are 123 counties with SHP installation of over 100 MW and 408 counties with the power generation over 100 GWh. From the resource distribution point of view, 1/3 of Chinese counties can rely on SHP for primary electrification in rural area.

Figure 10 SHP Development in China



The SHP potential mainly concentrates in two regions in China: the Yangtze River basin (includes most of the Southern region) and the Western part of China, eg. Tibet and Xinjiang provinces. The Yangtze River basin and southern region include 11 provinces: Yunnan, Sichuan, Guangdong, Fujian, Hunan, Zhejiang, Guangxi, Hubei, Jiangxi, Guizhou, and Chongqing. They cover mostly the mountainous regions that have abundant rainfall and rivers with steep gradients. The unique features have brought these areas with abundant SHP potential of 90,385 MW, accounting for 71.7 percent of total SHP potential in the country. These areas are becoming the key areas for future SHP development.

Tibet and Xingjiang autonomous regions are located at the foot of the Himalayas and of the Tianshan Mountain respectively. They are endowed with rich nature resource potential. The developable SHP potential accounts for 13.1% of the country's total. Nearly every county in Tibet and most counties in Xinjiang have developable SHP potential of more than 10 MW each. Therefore, these are also key areas for SHP development.

According to the Chinese national resource distribution, China's SHP resources are mainly concentrated in 13 provinces mentioned above. The Northern China State grids are mainly connected with coal generated power. The state grids mainly supply electricity to the urban population, industries and rural areas near the grid. The vast majority of mountainous regions face strong shortage in electricity. Some villages do not even have power supply. But most of these mountainous areas are endowed with abundant SHP potential that can be developed to fill in the gap of the large grid. For the past 60 years, China has accumulated a lot of experiences to realize rural electrification to meet the local conditions, through the adoption of appropriate technologies and measures and through self-reliance as well as using the locally available energy resources. Thus, while the central government concentrates on building the large grids and large power stations, the local government and local people are busy constructing the SHP stations and local SHP-based grids. The practice of equal attention being paid to the development of both large and small hydropower stations has promoted fast hydropower development in rural areas. And it has been found to be an effective strategy to solve the problem of electricity supply in remote and isolated rural areas.

In recent years, Water Executive Departments at various levels have attached great importance to the uniform planning and management of water resources. The measures include: 1. On the basis of unified planning and management, the review of water resources development should be enhanced; 2. The resources should be developed through fair competition and under governmental regulation; 3. Payment system should be established for using water resources; 4. The occupation of water resources is effectively curbed via fining and punishment, thus enhancing the management of water resources and accelerating the development of SHP under strict environmental requirements. Figure 10 shows the development of SHP in China as of the end of 2008. It can be seen from the graph that its development has scored a high percentage in eastern China while the national figure is only around 37%. In particular, the development proportion is still very small in Yunnan, Guizhou, Sichuan, Tibet and Xinjiang. There is a big potential for further development. SHP is always an important energy source for local socio-economic development, requiring expansion.

8.3 Recent SHP Development

In recent years, China's SHP continues its fast and sustainable development. In 2007, China witnessed an addition of 1,929 SHP stations with the capacity of 4,593 MW. At the end of 2008 the total SHP installed capacity reached to 51,400 MW which is more than the total hydropower installed capacity in 1995. The electricity produced by SHP stations reached 143.7 TMh. There are 408 counties having SHP production of over 100 GWh. Moreover, the construction of rural grid and power system has been strengthened. The development of rural electrification counties and pilot for fuel substitution by SHP is steadily progressing. The SHP development has improved the production and living conditions of local people, promoted rural economy, and made significant contribution to the rural environmental protection. In general, it has the following features:

- The scale of SHP is large and the development area is concentrated. In terms of the installed capacity, the top 4 provinces are Fujian, Guangdong, Sichuan and Yunnan with total SHP installed capacity of about 49.3% of the national total. The installed capacity of another 5 provinces--Hunan, Zhejiang, Guangxi, Hubei and Jiangxi-- representing 32% of the national total. The remaining 18% of SHP capacity is distributed among 23 provinces of which the 3 provinces of Guizhou, Chongqing and Gansu have a larger share. As shown in Table 14, the SHP capacity in China is mainly concentrated in these 12 provinces, accounting for 90% of the total. This represents the local resources advantage and the guiding role of local governments in SHP development.

Table 14 SHP Development in regions (2007)

Regions	**No. of Stations**	**Installed Capacity （MW）**	**Annual Output (GWh)**	**% of National Total (%)**
Fujian	6411	6325	19938	13.3
Guangdong	9195	5910	15034	12.5
Sichuan	4248	5866	24257	12.4
Yunnan	1784	5280	19522	11.1
Hunan	4788	4033	11204	8.5
Zhejiang	3233	3285	6703	6.9
Guangxi	2340	3152	7815	6.7
Hubei	2034	2391	6552	5.1
Jiangxi	3381	2276	5453	4.8

Guizhou	1285	1590	5540	3.4
Chongqing	1082	1141	3977	2.4
Gansu	618	1060	4021	2.2
An'hui	762	669	1176	1.4
Shanxi	964	665	2068	1.4
Xingjiang	374	603	2091	1.3
Qinghai	176	422	1942	0.9
Hebei	225	358	353	0.8
Jilin	167	350	1173	0.7
Henan	674	339	657	0.7
Liaoning	156	287	820	0.6
Hainan	326	270	773	0.6
Heilongjiang	69	236	398	0.5
Xinjiang Production&Construction Corps	75	218	888	0.5
Tibet	445	165	365	0.3
Shanxi	164	157	296	0.3
Projects directly under ministry	3	105	391	0.2
Shandong	97	72	84	0.2
Jiangsu	131	60	84	0.1
Inner Mongolia	36	53	89	0.1
Beijing	72	43	15	0.1
Tianjin	1	5	14	——
Ningxia	1	3	8	——

Total	45317	47389	143701	100

- The capacity per station is increased dramatically. However, it is mainly below 10 MW per station. According to the installed capacity, annual electricity output and the number of station, we may classify all SHP stations in China as shown in Table 15. From Table 15, we can conclude that the capacity of most stations in China is less than 1 MW, but most of the electricity production and installed capacity are still from the stations with several MW capacities. Moreover, the average installed capacity of a station increased from 27 kW in 1970s to around 100 kW in 1985 and reached over 1 MW in 2007. Nowadays, most of stations under construction are around several MWs, improving SHP economical benefits substantially. Moreover, from Table 15 we can also find that 98.1% of SHP stations have capacity less than 10 MW, which accounts 67.2% of the total installation capacity and generates 60.4% electricity. This also clarifies the misunderstanding that China's SHP is defined to be 50 MW, which by definition is similar to the LHP.

Table 15 Classification of SHP Stations in China (2007)

Type		1MW	1-10MW	10-25MW	25-50MW	Total
Station	No.	36984	7463	653	217	45317
	%	81.6	16.5	1.4	0.5	100
Installed Capacity	MW	10701	18992	9800	7896	47389
	%	22.6	40.1	20.7	16.6	100
Annual Output	GWh	25917	60970	40337	16477	143701
	%	18.0	42.4	28.1	11.5	100

- SHP and LHP develop synchronously. The installed capacity of SHP to that of LHP is always around 1:2. Table 16 shows the development of installed capacity and electricity production as well as their relations between 1985 and 2007. From these we can conclude that while the central government makes big investment to construct large hydropower stations and the Three Gorges, the local governments have also built many SHP stations. Nowadays, the scale of SHP stations under construction is about 20,000 MW per annum. Each year, there are about 2000 newly added stations. The new capacity in 2006 exceeded 5,460MW.

Table 16 Installed Capacity & Electricity Production of SHP (1985-2008)

Year	SHP		% of SHP in Total Hydropower	
	Installed Capacity（MW）	Annual Output（TWh）	Installed Capacity（%）	Annual Output（%）
1985	9521.0	24.1	36.0	26.1
1990	13180.0	39.3	36.6	31.1
1995	16646.1	55.4	32.7	32.6
2000	24851.7	80.0	31.3	32.9
2001	26262.4	87.1	316	32.7
2002	28489.3	94.7	33.1	34.5
2003	30833.0	97.9	32.5	34.8
2004	34661.4	97.8	32.0	29.8
2005	38534.4	120.9	33.2	30.6
2006	43183.6	136.1	33.2	32.0
2007	47389.0	143.7	32.0	29.8
2008	51300	155.6	29	27.0

- A number of counties see strong development in SHP, brings strong benefits to local economy. In 2007, there are 123 counties having SHP capacity over 100 MW, of which there are 26 counties having the capacity over 200 MW and 5 counties having its SHP capacity over 400MW. Shenjiang County, Yunnan Province has SHP capacity of 697 MW and it is the largest SHP county in China. In remote areas, SHP has become a pillar for rural economy, an important source of local governmental finance and channel for increasing income of farmers since it plays a big role in supplying rural energy, improving ecological environment, alleviating poverty, and promoting social development.

- In addition to large scale development, China has developed unique SHP management models. The power in the east can be connected to the State Grid and in the Midwest to local grids. At present, 583 out the 2300 counties in China take rural hydro power as the major power source. The power consumption in 2007 reached 565.8 billion KWh. The rural hydropower building in 2007 also solved the power shortage problem of 1.83 million people. The electricity coverage ratio of town, village and household in SHP supply areas increased from 91.8 %, 78.1 % and 65.3 % in 1985 to 99.66 %, 99.69 % and 99.48 % in 2007 respectively, solving the electricity usage of about 300 million rural people. Apart from the SHP plants invested by government for public benefits, there are also independent SHP plants invested by collective and individual for the purpose of profit and ecological SHP plants financed based on CDM model. The midwest and the east develop in tandem. There is more development in remote areas than the area covered by the State Grid.

- Due to the monopolistic characteristic of power industry, the SHP self-supply area has become smaller. Statistics show that in 1998 within the power grid service areas there were 541 power transformer stations with 110kV capacity, resulted a total capacity of 17,141 MVA. During the decade from 1998 to 2007, local power providers have built in total another 716 transformer stations of the same kind, with a total capacity of 34,480 MVA. However, since 2007 in the local power system only 584 1power transformer stations with 110kV remained, with a total capacity of 24,389 MVA. As a result of the planning, hosting and institutional changes, in the service areas of small hydropower stations, 673 transformer stations with 110kV and 110kV capacities were eliminated, with a total capacity of 27,232 MVA. Although departments of water resources and governments at all levels continuously put the efforts into the construction, 825,000 km of high-voltage lines and 1,923,000 km of low-voltage lines were eliminated, which causes reduced capacity of 48,295 MVA and the distribution capacity 52,812 MVA in the service areas of small hydropower stations nationwide. The tendency of narrowing down the size of local electricity grid in the service areas of small hydropower stations is very obvious. Under the current monopolistic power industry circumstance, small hydropower will not have its established market unless it reconstructs its service areas. These factors are harmful to the development of small hydropower in China.

8.4 Policies and Measures for Promoting SHP Development

After years of development, China has formed unique SHP management mechanism and support policy that are stated as follows:

- The county-based decentralized development and management mechanism and policy. The SHP development and management in China is decentralized and is managed by local governments and people. The State encourages to develop local SHP resources in the principle of “self-construction, self-management, and self-consumption” and implements the policy of “who invests should enjoy the revenue and ownership”, achieving good results.

- A set of policies and measures enabling the SHP development are issued. The government issues a series of laws, regulations and policy papers encouraging SHP development and creating favourable conditions for rural electrification. It also supports IPPs to have the development right to SHP, lowers the threshold, improves the review procedures, and signs power purchase agreements to secure the investment of developers.

- Set up preferential tax policy, includes project developers could be exempted from tax or paying tax at a discount rate within a period of time since its operation. Before 1994, SHP stations were only levied 5% of business tax. After 1994 a new tax system of 6 % value added tax was introduced for SHP business. This is still a good preferential policy for SHP developers, because VAT for large hydropower stations still remains at 17%. According to the new tax system, all companies operating in China are required to pay 25% as income tax; but in some counties SHP companies are exempted from the 25 % income tax, while in some counties, half of 25% only is collected from SHP companies as income tax.

- Use multi-channel funds collection to install power capacity, and use ‘the electricity generates electricity’ policy. Through rural electrification programme to encourage the whole society to implement SHP construction. Through loans from commercial banks and collect contributions from work places and individuals, government subsidies and furthermore land, labour and resources direct contribution, such various options could potentially fill the capital gap. The profits generated from SHP stations and local grids are not necessary to send to the local financial bureaus, but should be maintained with the county companies to build more SHP stations and to improve the local grids. This policy has been in operation for over 30 years. It plays a big role in enhancing the of development of SHP in China.

- Giving priority to the R&D and training tasks. To increase the cleanness of the SHP technology and to ensure the sufficient supply of its equipments in order to reduce the cost of production.

- The SHP development oriented and stimulated by the central government Large programs. For almost 30 years the central government has implemented several large programs including "County based primary rural electrification", "rural grid refurbishment and upgrading", "to send electricity to villages" and "to replace firewood with SHP electricity". Promoted effectively by these large programs with not a few governmental subsidies, the rapid SHP development has been sustainable for long period.

8.5 Suggestions to improve the SHP development

Since executed the "3-Self" policy and "electricity generates electricity" policy, the sources of funding to construct rural SHP projects have gradually transformed to a pattern which is local-based multi-channel fund raising structure, with limited portion comes from the state subsidies and investment. As shown in the table 17, the national expenditure for constructing SHP projects has reduced from 18.3% to 4.0% in the past 10 years, while the local self-financing construction radio has increased from 55.1% to 80.1%; if taking into account of the foreign investment and other sources of funding from local governments, the ratio has reached 96.0% in 2004. The pattern of local fund-raising to support local power generation has been formed, which has ensured and supported the country level long-term scale up of SHP development.

Several ways of mobilizing funding to support power generation at local level are:

(1) Government support. Each level of government sectors will release several millions of RMB as grants for SHP development. Also, there is a government policy, mandating all banks to create long-term soft loans delivery for SHP development projects. In recent times, the central government gradually pays more attention to the affairs of rural population, rural landscapes and agriculture; in particular bring more investment into SHP based rural electrification programs. For instance, for the State program of “send electricity to villages", the central government provided worth 50% of the

total programme cost as subsidies. For Tibet region, it is almost 100%. But for SHP based county rural electrification scheme, the assistance from central government is not to exceed 5%. For the "replacing firewood with SHP electricity "scheme in the fringes of forests: in western provinces up to 50%, in the central region up to 40% and in the developed eastern provinces not more than 30 % is the central assistance pattern. For SHP IPPs, there is no central allowance for the commercial development.

(2) Local county company's rolling investments. After several tens of years investment into SHP development, many county companies raised funds through accumulated profits from the existing stations and this is called "electricity generates electricity" funds. Recently, these funds increased dramatically.

(3) Fund rising from local population. Generally, local people are always willing to develop SHP resources that is very close to them. Chinese government is giving priority to assisting and organizing local population to meet their immediate energy needs by developing their SHP stations and install / reinstall local grids. Some local residents, who have no money, offer themselves for work without pay, in the buildings of the stations and grids. Eventually, the SHP based county rural electrification scheme has become part of the poverty alleviation program.

(4) Loans from banks. In the past ten years, financial companies and banks have gradually become the major sources of funds for SHP development. For instance, China Agricultural Bank and China Construction bank have established a special SHP loan scheme to support SHP development. Table 17 shows the funding sources during 1998-2007. It shows that the central government allowance is decreased from 18.3% to less than 4.0% in 2007, locally collected funds increased from 17.1% to 39.35% in 2007, and loans from banks increased from 38% to 40.9% in 2007. With the development of market system, the banks and other financial institutions are becoming more committed to the funding of SHP development.

Table17 Funds Sources for Rural SHP Development (1998-2007), RMB100 billion

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
State Investment	0.88	2.33	4.38	3.02	4.54	3.59	2.26	3	8.48	2.11
Domestic Loan	6.91	7.38	10.4	11.9	11.4	11.9	15.6	17.8	20.2	21.4
Foreign Investment	0.27	1.13	1.38	8.05	0.36	1.05	1.2	19.1	12.0	16.9
Self-finance	5.31	5.51	6.72	4.98	6.13	10	14.5	18.2	19.4	20.5
Others	2.5	2.42	2.2	2.03	2.28	4.41	4.11	4.09	5.98	6.56
Total	15.9	18.8	251	291	248	310	377	450	523	523

(5) Implementing share-holding system in fund collection. Since the beginning of 1990, most of the

SHP stations use the share holding system to raise funds. Until the end of 2007 China has more than 28,934 SHP businesses, local cooperatives or private companies, of which about 83.6% are registered as share holding companies, as shown in Table 18. This system has become very effective in attracting funds.

Table 18 Classification of SHP Organizations with Independent Accounting (2007)

Name	Organizations Independent Accounting	Public Institutions	Businesses			
			Businesses (Total)	State Owned	State Holding	Others
No.	28,934	2,219	26,715	2517	1402	22796
%	100	7.7	92.3	8.7	4.8	78.8

(6) Small IPPs (Independent power producer) direct investment. Nowadays, it becomes more and more common that SHP investment directly comes from outside developers. Since the outside developers can also make application for local bank's long-term loans for SHP development, if themselves have basic capital around 20-30% of total project budget. And normally, the local government will make some special measures and policies to welcome and to give priorities to the outside development. So, normally this commercial SHP development could get quite good results and the payback time will be about 6-10 years. Even though for all nations' different types of SHP stations' average, i.e., including some social and environment oriented SHP stations for replacing firewood, for improving rural electricity coverage ratio and for Tibet as well as other remote areas, the economical benefits of SHP industry in China has been effectively improved. Table 19 shows during the past 10 years the main economic index of SHP industry. From the table we can find that per person profit and tax is increased fast and reached the average level of other industry in China. The average profit for property is also improved.

Table 19 Financial Indicators of Rural Hydro Power Businesses (1998-2007)

Year	**1998**	**1999**	**2000**	**2001**	**2002**
Fixed Assets (RMB100 M)	1068.4	1216.2	1497.1	1616.3	2280.4
Annual Profit & Tax (RMB100 M)	42.7	38.4	42.5	44.7	63.3
Employment (0000')	52.8	53.1	53.9	54.0	62.2
Profit & Tax Per Capita (RMB/person)	8087	7232	7885	8278	10177
Profit Margin (%)	4.00	3.16	2.84	2.77	2.78
Year	**2003**	**2004**	**2005**	**2006**	**2007**

Fixed Assets (RMB100 M)	2370.1	2686.5	3040.0	2938.3	3647.7
Annual Profit & Tax (RMB100 M)	84.6	85.6	116.3	124.0	152.0
Employment (0000')	64.1	65.9	66.2	65.1	65.0
Profit & Tax Per Capita (RMB/person)	13198	12989	17541	19048	23385
Profit Margin (%)	3.57	3.19	3.83	4.22	4.17

8.6 The Technical Development of SHP in China

8.6.1 The Main Technology Innovation Results of SHP in China

Studies on river development and rural electrification. Stream cascade development is one of the main characteristics of SHP development in China. It can take full advantage of the hydro energy of a river, and the leading reservoir constructed in the upper reaches can regulate the downstream flow of all power stations. SHP-based rural electric planning includes the development of hydropower resources, the balance of electricity consumption and economic calculation. As a result of big changes of peak-valley load and between output of flood season and dry season, it is suggested to set up two-ways planning of power building and load development at the same time, as well as to recommend an electricity consumption standard with specific Chinese characteristics in rural electrification, which is the first time appeared in the international community, and it received first prize of the scientific and technological progress of Ministry of Water Resources (MWR).

Research in local power grid construction and its management. Such research shows the need for the existence of local power grid, and provides a set of technologies and methods for the operation and management of local power grid. The possible nearest power generation and supply can take full advantage of the nearest water resources, with a combination of managing water and generating electricity. The unification of electricity generation, supply, and consumption is implemented in local power grid, with self-generation and self-supply as the main function and online transactions available for redundant power. The guideline of large grid by the State and small grid by local governments ensures the rapid development of the electricity market in the rural areas, and enables SHP to have its own service areas and relatively stable power users, creating different ways of rural power supply and consumption compared with other countries.

Research in improving the reliability of SHP and annual electricity output. Compare with large hydropower, the reliability of small hydro power generation and power production per kW installed capacity is much lower. The research will aim to improve the quality of SHP equipment and to fully realize the seasonal electricity generation, to enable the annual average use of installation increase from 2000 hours to more than 3270 hours, and to analyze the impact of hydrological data shortage and to use the average monthly flow calculation to determine the installed capacity and to design several practical estimation methods.

Innovative research in SHP hydraulic structures. The research provides various SHP development forms and diverse forms of hydraulic structures. Many new technologies, materials and findings of hydropower building in China are used firstly in SHP projects, such as roller compacted concrete face rockfill dam, roller compacted concrete dam and filling-in rubber dam, which are tried and deployed in SHP industry. The filling rubber dam is also used to replace the gate reservoirs spillway when necessary. The local material dam and non-pressure water diversion structures which are not common in the large-scale hydro power are used, including the low dam backwater, non-pressure intakes, settling facilities, diversion canal, and fore bay. The hydraulic automatic start-stop siphoning intake study was firstly deployed in the northwestern areas of the country and then was widely used in the whole country. The fore bay volume design has been an unclear problem. In the 1990s, according to the research and analysis, the fore bay section is only related to surge calculation and fore bay design specifications were developed for the first time. The study on the sand prevention and flushing of SHP has progressed both in theory and practice. The vortex-typed sand flushing has been applied initially.

The cost-effective mechanical and electrical technology research. Since SHP requires technical adaptation and economy and it develops towards standardization, automation, information, the research focuses on promoting the application of cost-effective clean technology. The work has produced a range of patented technologies represented by multi-nozzle inclined-jet turbine, electric pitching while having developed related auxiliary equipment. Having reached advanced international level, the newly-developed products, apart from meeting domestic demand, are also exported to more than 40 countries and regions.

Research into the technological transformation of SHP stations. Due to the poor conditions in early years, some design parameters largely deviated from the actual situation, so some SHP stations built in early years have delivered inadequate output or abandoned large quantity of water. Some other stations, due to the poor quality of electromechanical devices and low operation reliability, need technological improvement. The research has proposed methods to enhance the turbine efficiency or machine capacity, raise power plant automation level and promote computer application. With the features of less investment and quick results, these methods can generally increase capacity by up to 10 **%**, so the technology transformation investment can be profitably recovered only in two or three years.

Research into SHP development policy and standards. For the development of SHP in China, the research has formulated more stringent specifications and related technology standards and has clearly defined the relevant project establishment and approval procedures and relevant policies and regulations involving various factors of developing hydropower, such as the acquisition of development rights, land use permits, the impact of immigration, assessment of environmental impact on the local community and the public. In addition to that, the research has specified the requirements concerning power plant building and operation, so that the disorderly development of SHP has been prohibited. Many methods are peculiar to China and have had a significant impact in foreign countries. For instance, the "Three-Self" principles, the policy of using the profit from SHP to develop SHP and local grids, the policy of developing service areas of SHP, and the policy of unified water resources management.

Clean development mechanism and countermeasures research into China's hydropower carbon financing. The research produced the *Research Report on China's Hydropower Clean Development Mechanism*. The project of Yuzaikou station in Rucheng, Hunan Province has been approved by NDRC in 2005 and has got successful registration with the CDM Executive Committee as the first Chinese hydropower project, thus making China, a great power in hydropower, fill the blank in the international CDM area. This will generate great economic and ecological benefits.

Research into sustainable development of rural power systems. The "three electricity markets" theory has been proposed—establishing a competitive market in traditional power system, setting up a local service-oriented market in the majority of the large rural mountainous areas, and establishing a user-side distributed market in the existing grid-covered region. This theory has conducted a theoretical innovation for the cause of Chinese rural electrification in the new era.

8.6.2 The Comparison of Main Technology and Characteristics of SHP at Home and abroad

1. Comparison of electromechanical technology of SHP

--Small hydroturbine. The highest model efficiency of a francis turbine has reached 94.2%, reaching advanced international standard. Traditional structure of small axial-flow units include generating layer and turbine layer, which are combined into single-layer structure now, simplifying the layout of hydraulic structures. Using electric propeller technology has changed the traditional hydraulic turbine propeller, which is the first case in the world. Tubular turbine using two-way generation and two-way outlet is internationally advanced. It has filled the blank in the development of tidal energy in China, receiving the second prize of the national scientific and technological progress. Impulse water turbine uses the new structure with thickened water skip root and appropriately reduced water skips. No similar products have been reported. Inclined-jet turbine enlarges its specific speed scope, raising its application head up to 400 meters, much higher than that of those recommended products of the same kind in foreign countries, 120 m.

--Small hydro-generator. It sees widespread adoption of new technologies, structure, and materials, whereas compared with foreign countries, its structural design, process technology, use of materials still have a gap compared with foreign countries.

--Micro integrated units. There are various series with technology at the global scale. Turbine rotors use the new technique of precision stainless steel monoblock casting. The generator is of rare earth magnetic generators, uses brushless non-excitation system and utilizes electronic technology to solve the voltage stability problems of micro-hydropower units, therefore improving the operating safety and simplicity of micro-hydro power devices. Micro-hydroelectric mobile power station and box-type micro-hydropower generating units have also been developed.

--Electrical equipment. Computer and information technology is widely adopted to improve the reliability of hardware and software and to build network-based monitoring system for simplified operation and maintenance. Automatic control, adjustment, protection, data collecting and logging, accident recording of hydro power stations are adopted to achieve a high degree of automation, so few or no people are on duty. This improves the power station in its economy, reliability and safety. But the R&D of high-tech products characterized by automation and informationization still lag behind similar products from foreign countries.

--Auxiliary equipment. Automatic speed regulator, heavy hammer-type valves, low-speed and no-bushing bearings, and low-noise accelerator have developed rapidly with improved parts and components quality and performance close to the international products of the same kind.

--Standardized production. SHP equipment abroad mostly adopts single-piece production, with the shortcomings of many processes and high cost. Different from foreign countries, China promulgated the industry standard for small turbine, and the turbine generator, governor and gate are also designed in series. In recent years, research units and equipment manufacturers have marked their products in series. Some internationally advanced high-performance runners have been put into application.

2. Characteristics and technical comparison of small hydraulic structures

--Low dam water-diverting structure. In low dam design, only stability and safety are analyzed and the structural stress of dam body is not analyzed. During stability analysis, shearing strength formula was used instead of shearing resistance formula. Due to the weak supporting strength, solid gravity concrete structure was not applied in order to reduce cost. The usage of hard-shell dam is a typical example.

-- Sand prevention and flushing measures of non-pressure inlet. Bottom stockade diversion structure was initially built in the Austrian Tyrol region. After the importation, China has made in-depth studies and improvements. Intake with under sluice pocket structure was first built in India. After improvement by Chinese people, it uses skew intersection of head gate and dam axis and set sand-guide sills to improve scour-and-fill of sand flushing on the riverbed either before water gate or after the gate. The technology has achieved good results and has been acknowledged internationally. No-pressure open water intake uses vortex-type settling tanks behind water intake. It is capable of handling all the bed load silt and excluding more than 85% of suspended load silt of 0.05-mm particles, which is an efficient water-saving and energy-saving sand flushing technology.

--Plant. The plant structure of the small hydro power and the layout of electromechanical devices are directly related. Plant design and construction have become increasingly innovative and modern. New electromechanical device and automation technology have changed the past established design, emphasizing its outside design, requiring harmony with the external environment and using the free-reflection sound-absorbing material to prevent the noise of the plant. A single layer plant is adopted by small vertical axial flow hydraulic turbine with new structure.

8.7 Problems in Developing SHP

SHP in China is often referred to as a backward technology. Some people think the industry has ceased developing. In other cases, this argument is based on the external relationship between large grid and small grid. But these "backward and exogenous "theories are not in the interest of SHP development. There should be a full understanding of the problems in SHP sector:

--Smallness is an essential part of SHP industry. Nowadays, the size of SHP in China is getting bigger and bigger. In China, SHP stations are defined as those with installed capacity below 50 MW while the international standard is 10 MW. The bigger capacity will weaken the difference between LHP and SHP. It will also be difficult to implement the State policy to support the SHP industry development. Therefore, SHP must maintain its essence of smallness if it wants to achieve sustainable development.

--Decentralized operation and lack of industry cohesion. Although China has many SHP stations and policies on loan, tax, resources development and application of new technologies, the 45,000 stations are owned by 29,000 businesses each of which has many shareholders. So the ownership is not clearly defined. SHP assets and service areas are often hosted or invaded, causing the disorder in the rural power market covered by SHP.

--Less available resources and more environmental constraints. It is natural that as more SHP stations are developed, the number of potential sites would decrease. This means less option for SHP potential sites and higher construction cost. On the other hand, owing to the lack of planning and coordination in resource development at different levels of government, the environmental constraints have been worsening.

--Managing and coordinating the relationship between local and large grids has become a serious problem. The building of SHP relies on local government under a decentralized market economy system, while the building of LHP relied on central government with its monopolistic and centralized management structure. These differences between local and large grids usually generate serious conflicts, for example, to supply SHP electricity to large grid is not always accepted and the tariff is even lower than its cost. The low tariff and high building and operation cost will cause SHP to have low economic benefits.

--Emphasis on building and not on management. When developers and local government are mainly focusing on building more stations and exploiting the available potential, with little attention to key issues, problems would certainly erupt in the industry. Some of these important issues include developing without unified planning and management, and project without formal design, approval and acceptance. All these issues are vital and would have a significant impact on the future SHP development.

--Technical issues. Although many SHP stations have been constructed and some technologies are improved, yet there are still many technical problems need to be addressed. Lack of interest in technology innovation is the major issue. Only few stations use new technology for upgrading and refurbishment. Low annual utilization hours, high transmission and distribution losses, low level of automation and the quality of equipment needs to be further improved. The above issues are not isolated. To find a satisfactory solution, it is essential to understand the relationship between them, especially the relations between local grid and large grid, to clarify the position of SHP in the new era, to strengthen the function at all levels of the governmental department of water resources, and to make them as the real backbone and representative of SHP to lead the whole industry to improve itself. If these obstacles can be removed, then the SHP development will enter a new era.

Therefore, measures need to be prepared in advance to stimulate a further sustainable development of SHP in China.

8.8 SHP Experiences in China

There are many factors can explain the fast development of SHP in China in the past decades, and it could be summarized into the following:

- Government support. Chinese government has made many preferential policies, such as tax reduction policy, policy on soft loans or grants from government, promotion of private firms to invest in SHP stations and policy to protect SHP supply areas and owner property. In 2007, the central government released loans and grants of RMB2.1 billion, and made a total investment of RMB52.3 billion. Nevertheless, it is worth mentioning that the ratio of central government investment to that of the private and individual contribution is only 1:25.

- Driven by large programs of the central government, such as rural electrification, rural grid upgrading and refurbishment, sending electricity to villages, replacing firewood with SHP electricity, small river basin treatment, returning arable land to forestry, rural environment protection, and electricity demand by township businesses, the scale of SHP investment and building are greatly expanded, meeting the needs for electricity in vast rural and mountainous areas.

- Systematic research for SHP operation, maintenance and management has been conducted. Many featured technologies are developed and policies, codes, and standards are issued. China has become the SHP demonstration country in the world. The environment protection, power industry reform and management need to be enhanced.

- Having big SHP potential, good decentralized development and management mechanism, as well as effective policies, measures and many unique technologies, the SHP will sustain its fast development in future. In fact, the planned 50GW SHP installed capacity for year 2010 has been completed in 2008. It can be expected that the 93GW SHP installed capacity planned for 2020 will be realized too.

- The problems that restrain the SHP development will exist for a long term. Operation and management of local grid and SHP supply area are still very difficulty. Supplying SHP electricity to large grid is not always accepted and with the unreasonably low tariff. The resources and environmental constraints are barriers. The central government needs to pay much attention to

SHP development.

9 Conclusions and Outlook

9.1 How Far is China from Its 2010 Renewable Goal

Overall, the renewable energy development is far from balance between different technologies. As for wind, the development target for 2020 will not only be achieved but also be overtaken. For instance, the planned installation of 30 GW might be exceeded by an actual installation of 100 GW. The solar thermal utilization target of 300 billion m^2 will be upgraded to 500 billion m^2. The solar power generation will run an even quicker trail, achieving a total installation of 10-20 GW instead of 1.8 GW as planned for 2020. The biggest barriers remain with biomass. It seems difficult to reach the targets for both biomass power and biofuel that are set as 30 GW and 12 Mt respectively by 2020.

Main barriers to be removed for different sectors are as follows:

- For wind, the grid-connection constraints need to be resolved, along with the stability and reliability of equipment, and the developing model needs to be shifted from installation-focused to generation-focused;
- For solar water heater industry, the speed-up of the industry relies on the enforcement of mandatory installation and the fiscal subsidy of rural utilization;
- For solar power generation, the cost needs to be further decreased and the reliability of the products needs to be improved while the high energy consumption and pollution in silicon material production need to be addressed as well; and
- For biomass power generation and biofuel development, more efforts need to be made in the feedstock collection and the second-generation technology advancement respectively.

9.2 Enhancing the Strategic Role of Renewable Energy in Mitigating Climate Change and Ensuring Energy Security

Renewable energy development has been listed as a primary instrument for China to tackle climate change and GHG emission reduction in the State Action Plan for Climate Change released in June 2007. Similar statement was made in *the ReLaw* as the legislation principle, quoted as "the purpose of this law is to promote the development and utilization of renewable energy, increase energy supply, improve the energy structure, safeguard energy security, protect the environment, and realize the sustainable development of the economy and society". In November 2005, President Hu Jintao expressed the role of renewable energy in his congratulatory letter to the International Renewable Energy Conference Beijing 2005 as "to enhance the deployment of renewable energy is a critical part and the only way to deal with the increasingly severe energy and environmental challenges, and also one of the essence opportunities leading to a sustainable future of human being". Chief of National Energy Bureau also highly advocates the development of renewable energy and takes it as a major action to bring energy industry through the crisis. As a conclusion, the role of renewable energy development is strategically positioned.

Some restraining factors remain to be addressed. They are:

- Insufficient investment in R&D of renewable energy technology. The innovation capacity is lagging behind many European and North American countries.

- Pricing scheme of renewable energy generation has not been optimized; the investment payback is hard to anticipate; revenues from CDM are fluctuating.

- Support from grid companies and other associated monopoly companies is insufficient, holding back the grid connection of renewable electricity and marketing channel for biofuel.

- Target for solar PV is unclear. Market environment for solar PV is not in place yet.

To address these problems, joint efforts are needed from Chinese government, businesses and the international community, to:

- Scale up the R&D investment and international cooperation in renewable energy technologies, support the establishment of a technology R&D and innovation centre for renewable energy in China to back up the sustainable development of renewable energy.

- Establish a favorable policy framework for renewable energy, especially the pricing scheme and the subsidy mechanism, stabilize the CDM mechanism, and reduce the transaction cost of CDM.

- Remove barriers holding the acceptance of renewable energy by monopoly companies and increase the capacity of grid to accept wind power and other renewable power.

- To establish a stable market for PV not only domestically but also internationally, creating a sound policy and market environment for a steady and healthy development of PV industry.

Abbreviations and acronyms

BIPV	Building Integrated PV System
Bt	Billion tons
Btce	Billion ton of coal equivalent
CAE	Chinese Academy of Engineering
CBM	Coal-bed methane
CPC	the Communist Party of China
FYP	Five-Year Plan
Gce	Gram of coal equivalent
GHGs	Greenhouse gases
GW	Gigawatt
IPCC	Intergovernmental Panel on Climate Change
Kgce	Kilogram of coal equivalent
LSPV	Large scale PV
MFA	Ministry of Foreign Affairs
MII	Ministry of Information Industry
MOA	Ministry of Agriculture
MOC	the Ministry of Construction of China
MOF	Ministry of Finance
MOST	Ministry of Science and Technology
Mt	Million tons
Mtce	Million ton of coal equivalent
MW	Megawatt
NBS	National Bureau of Statistics of China
NDRC	National Development and Reform Commission
NEA	National Energy Administration
RDD&D	Research, development, demonstration and deployment
ReLaw	People's Republic of China Renewable Energy Law
SERC	the State Electricity Regulation Commission （SERC）
SOE	State-owned enterprise
sq.m	Square meter
SWH	Solar water heater
T	Ton
Tce	Ton of coal equivalent
tpa	Tons per annum
UNEP	United Nations Environment Programme