China Renewable Energy Development Overview (2008)

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Preface

Renewable energy (including hydropower, wind power, solar power, biomass energy, geothermal energy, and tidal power, etc.) is a resource with tremendous potential. Renewable energy resources are environmentally friendly, with little to no pollution, and can be utilized continuously and sustainably. Renewable energy is an important resource enabling the harmonious development of people and nature. Since the 1970s, sustainable development has gradually become an internationally recognized goal. The development and adoption of renewable energy has received a high degree of attention from countries around the world, and many countries incorporated renewable energy to be a major component of their energy strategies. These countries set forth clear renewable energy development goals and instituted laws and preferential policies to encourage renewable energy development. Renewable energy has developed rapidly since then and has become the fastest-growing energy source. Commercial utilization of such renewable energy technologies as photovoltaic (PV) cells and wind-generated power has achieved growth rates of over 20% in the last ten years. In addition, liquid biofuels have grown at the rapid rate of 60% in the last 5 years. Renewable energy has become a hot topic in the global energy industry.

As a major consumer of energy, China recognizes the high strategic importance of renewable energy in energy legislation. As such, renewable energy has played a major role in legislation concerning environmental protection, lowering greenhouse gases (GHG) emissions, and the rural electrification campaign. The promulgation and implementation of China's *Renewable Energy Law* ("RE Law") signaled China's renewable energy industry's entry into a new stage of development. Particularly in 2005 and 2006 renewable energy development received widespread attention and recognition, and the scale of the renewable energy market expanded rapidly. Investment and inputs into renewable energy increased drastically, and the renewable energy manufacturing industry took off, achieving a positive international impact and attracting widespread interest from global society. China may become the biggest market for renewable energy in the world, and has huge potential to become a major manufacturer of renewable energy equipment. In September 2007 the Chinese government promulgated the *Renewable Energy Mid- to Long-term Development Plan*, inevitably promoting phenomenal progress and development in China's renewable energy sector.

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1.1 The Background of the RE Law

The Chinese government has long tried to adopt energy investment policies which include developing renewable energy and other new energy sources. However, China's energy legislation process is relatively slow. This is a common issue and China's renewable energy legislation is no exception. As China's energy legislation unfolds/is carried out, some similar laws (*Electricity Law, Resource Saving Law, Building Law, Prevention of Large Gas Pollutants Law,* etc.) involved measures to promote the development of renewable energy. But all in all, before the "RE Law" came out, renewable energy's development came mainly through state-level regulatory development, such as the State Planning Commission's (now the NDRC) *New Energy Basic Infrastructure Project Management Zanxing Rules* (1997), the *Management Measures on Straw Combustion and Comprehensive Utilization* (2003) by the State Environmental Protection Agency (SEPA), etc. Because China's renewable energy legislation has been seriously lacking, and because renewable energy by nature is not necessarily market oriented, renewable energy is not yet mature and independent enough of an industry to effectively attract foreign and domestic investment.

Following the Chinese economy's rapid development, a gap between energy supply and demand has emerged. The energy problem grows more serious every day and traditional patterns of energy exploitation and utilization are causing daily deterioration of China's environmental problems. Given these increasingly serious issues, speeding up the development of renewable energy has already become the Chinese government's major strategic energy strategy choice. In order to promote the development and utilization of renewable energy and deal with/overcome the barriers standing in the way of realizing this goal, the 2003 the tenth session of the Standing Committee, National People's Congress (NPC) took development of the RE Law into the schedule for the year 2003 legislation. Working together with the sectors of the State Council, relevant research institutes and social communities, the Environmental and Resources Protection Committee of NPC drafted the RE Law and submitted for NPC for discussion and review in December 2004. Reviewed by 13th and 14th sessions of the Standing Committee, NPC, the RE Law was passed on February 28, 2005 and put into effective on January 1, 2006.

1.2 The Five Regulations of the RE Law

Countries around the world look to renewable energy development and utilization as a strategic step to supplement overall energy supply and solve future energy issues. Based on many countries' experience in this area, the state has a clear responsibility to promote the development of renewable energy, and extra costs incurred by the development and utilization of renewable energy must be shared by all consumers. Otherwise large-scale adoption of renewable energy will not be possible. In China today, the government is the central force promoting the development and utilization of renewable energy, but the government's goal in this policy is to speed up renewable energy's commercialization and scaling up. The government's main responsibility lies in building, regulating, and standardizing the market for renewable energy, thereby using the market structure to enable and encourage mainstream development and utilization of renewable energy sources in the market. In this vein, the Chinese government has put forth five major regulations in the RE Law: the Renewable Energy Target Policy, Feed-in Law, Categorized Pricing, Cost Sharing and Special Fund Mechanisms.

(1) Renewable Energy Target Policy. To define the national target for renewable energy development and to identify phased development goals, as well as clarifying which fields or sectors will be supported, encouraged, constrained, or designated for investment. The accelerated development of China's renewable energy industry should be promoted by a combination of government encouragement and market guidance.

(2) Feed-in Law. As a condition for energy sale network's monopoly operating and licensed operating, the enforcement of the Feed-in Law will ensure the development of the renewable energy industry's basic system. This law will reduce transaction costs, shorten renewable energy projects' market entry lifecycle, and increase credit for project financing, thereby contributing to overall development of the renewable energy industry.

(3) Categorized Pricing Mechanism. To categorize the price of power generated according to various costs of different renewable energy technologies and to develop and publicize the reasonable fixed electricity price or bidding price.

(4) Cost Sharing Mechanism. To ensure fairness in policy and laws, and to ensure that citizens fulfill their obligations and the state fulfills its responsibility, the extra cost of renewable energy should be shared equitably among different regions. This cost-sharing mechanism effectively resolves the problem of unfair cost burdens between regions and businesses, thereby promoting the large-scale development and utilization of renewable energy.

(5) Special Fund Mechanism. The cost sharing mechanism described above will

resolve most problems with the extra cost of renewable energy. Further cost-related bottlenecks in the development and utilization of renewable energy will need to be solved through special channels, necessitating the establishment of a Renewable Energy Special Fund to support such fields the cost sharing mechanism cannot cover, such as financial support for renewable energy research and development.

1.3 The Enforcement of the RE Law

The RE Law passed on February 28, 2005 established a full set of legal structures and policy steps and provided the legislative and policy framework for improvement of renewable energy development.

To ensure the smooth implementation and strengthen the effectiveness and practicality of the RE Law, the National People's Congress and the sectors related of the State Council began developing implementation regulations. Six important government ministerial sectors (the Law Committee, Legislation Committee and the Environmental and Resource Protection Committee, National People's Congress, National Development and Reform Commission, Ministry of Finance and the Ministry of Science and Technology) jointly called for seminars on implementation issues of the RE Law. In this context 12 actions were adopted in the implementation regulations for the RE Law and responsibility for implementation of these regulations was assigned to relevant sectors of the State Council.

Currently, the set of implementation regulations already issued is as follows:

- *The Guide to Renewable Energy Industries*. A brief introduction to renewable energy industries, technologies, equipment and the relevant indicators. To further establish and implement policies in related industries and tax incentives.
- *The Renewable Energy Power Generation Management Measures.* The clear identification of administration system, project management and grid-connection for power generated by renewable energy.
- *Trial Measures for Managing Prices and Cost Sharing for Grid-Connected Renewable Energy.* Specific regulations on legal pricing and cost sharing for grid-connected renewable energy generators.
- Survey on renewable energy resources and technology regulations. The NDRC has already completed an assessment of China's hydropower resource and clearly established estimates of the capacity of China's hydropower resources. The NDRC is now carrying out the national wind energy resource investigation, wind site assessment and biomass energy

resource assessment.

- The Ministry of Finance has incorporated the Renewable Energy Development Special Fund into the national budget and established Management Measures for the Renewable Energy Development Special Fund. Related financial subsidies and preferential tariffs are being developed according to the needs of the sector.

Technology regulations and standards have been issued as follows:

- *Technical Regulations on the Application of Solar Water Heating Systems in Civil Construction* and *Technical Regulations on the Application of Geothermal Pumping Engineering* have been completed by the Ministry of Construction.
- The following 6 national standards have been issued by the Standardization Administration Committee: *Technical Requirements for Grid-Connected Solar PV Systems*, *Wind Turbine Power Generation Part 1: General Technical Requirements*, *Wind Turbine Power Generation Part 2: General Testing Methodology*, *Technical Regulations for Wind Farms Connecting to the Grid*, *Technical Regulations for Geothermal Generation Systems Connecting to the Grid*, and *Technical Regulations for Solar PV Systems Connecting to the Grid*. The technical standards for technical condition of flat-plate solar heat collector, the testing methodology for solar heat collector performance and vacuum-tube solar heat collector are under research.

In addition to the aforementioned set of regulations on the overall development of China's renewable energy sector, government bodies have developed certain special regulations or guiding documents together, such as *Implementation Measures for Improvement of Wind Power Industry*, the *Notification for Enhancing Administration of Ethanol Biofuel Project Construction and Improving Sound Industry Development*, the *Implementation Measures for Finance and Tariff to Support Development of Biomass Energy and Biomass Chemicals*, the *Trial Measures for Management of Special Fund of Renewable Energy Construction Application* and the *Assessment Measures for Renewable Energy Construction Application Pilot Projects*, etc. All these documentations and regulations are promoting renewable energy technology improvement.

1.4 The Impact of the RE Law

It has only been one year since the implementation and enforcement of the RE Law began, but it is already making a great impact on society.

1.4.1 Renewable Energy Attracts More Attention

Since the RE Law was drafted in 2003, people from levels of society have attained increasingly clearer understanding of renewable energy. Officials at all levels, but especially national top leaders such as President Hu Jintao, Wu Bangguo and Prime Minister Wen Jiabao, have displayed great attention toward renewable energy and have commented on it numerous important occasions. The Environmental and Resource Protection Committee of NPC and the NDRC have twice called for symposiums on implementation issues of the RE Law. Awareness of renewable energy at all levels of society has grown significantly.

1.4.2 Renewable Energy Market Expands Rapidly

China’s renewable energy sector entered into a new stage of development when implementation of the RE Law began on January 1, 2006. All types of renewable energy grew rapidly in 2006: the annual installed capacity of hydropower reached 10 GW with cumulative installed capacity a full 129 GW; the annual installed capacity of wind power was 1.332 GW, more than the sum of accumulated installed wind power capacity in the last 20 years, or an increase of 270% from 2005; annual solar PV cell production reached an unprecedented 370 MW, an increase of 150 MW from 2005 and the equivalent of 15% of total global production; solar water heater production capacity reached 20 million m^2, an increase of more than 2 million m^2 from 2005, with a total of nearly 100 million m^2 of solar water heaters in use. Biomass development and utilization is also progressing rapidly, with more than 9 billion cubic meters of biogas utilized and 2600 biogas projects underway.

Annual renewable energy use is up to 200 million tons of coal equivalent (tce), comprising approximately 8% of total primary energy consumption. This proportion is an increase of 0.5% since 2005. Within this sample/proportion, hydropower electricity generation makes up 15 million tce while solar, wind, and modern biomass energy make up 5 million tce. All of these achievements have established a solid base for achieving China’s goal of having renewable energy comprise 10% of total primary energy consumption by the year 2010.

1.4.3 Renewable Energy Investment Increases Significantly

Thanks to the implementation of the RE Law, the investment risk for renewable energy has been significantly reduced. Various investors have begun to enter China’s renewable energy sector. Large domestic state-owned enterprises such as the State Grid Company, five power generation companies, three big petroleum groups, Shenhua Group Corporation, China Yangtze Power Co., Ltd. as well as some provincial energy companies have become active players in the renewable energy market. Shanghai Electric Group, Dongfang and others are also getting involved with renewable energy equipment manufacturing. Major international wind turbine manufacturers as well as some Chinese private enterprises are also entering the Chinese renewable energy market on a large scale. Today's solar power industry is basically controlled by private capital. At the same time, private equity and venture capital players have begun to invest in China's renewable energy. By the end of 2006, 15 Chinese renewable energy companies had gone public on the major stocks of New York, London, Hong Kong, Singapore, and local domestic stock exchanges, now with a total market value of more than US$10 billion. At present, there are at least 20 renewable energy companies preparing for IPOs. With additional IPOs there will be at least 20 listed Chinese renewable energy companies valued at more than US$20 billion by the end of 2007.

1.4.4 Renewable Energy Manufacturing Launching and Developing Rapidly

Thanks to the combined pushes of the government and the market, investment – particularly private equity and venture capital – has ignited strong growth in the renewable energy manufacturing sector. Manufacturing of renewable energy equipment, especially for wind and solar power, has developed very rapidly. As of the end of 2006, there are more than 100 enterprises producing wind turbines and related components, among which there are 36 large-sized wind turbines manufacturers, 4 wholly foreign owned enterprises (WFOEs), 3 joint-ventures and 29 domestic enterprises. Domestic wind turbine producers have seen their market share in China increase significantly: in 2006 the market share of domestic companies reached 40%. There are more than 10 Chinese solar PV cell manufacturers with annual production greater than 100MW each, two of which are among the top ten PV cell manufacturers in the world. There are more than 3000 solar water heater manufacturers, among which over 10 companies have sales revenues of more than RMB 1 billion. At the same time, large international equipment manufacturers have invested in China and are working to improve China's renewable energy manufacturing industry. These companies include major international names like GE (USA), Gamesa (Spain), Vestas (Demark), Nordex (Germany), and Suzlon (India).

1.4.5 Renewable Energy Impresses on International Community Greatly

The RE Law and the achievements it has enabled in China's renewable energy sector have generated a positive response from the international community. High-level international conferences such as the 2005 Beijing International Renewable Energy

Conference, the 2006 New York World Sustainable Development Conference, and the G8 Summit gave high praise to China's proactive and effective approach to the development of renewable energy. Major governments and organizations around the world have incorporated renewable energy into their cooperation with China. For example, since 2006 the majority of European Union (EU) renewable energy R&D projects have been open to participation from Chinese experts; renewable energy is one of the important cooperation programs of Asia-Pacific Partnership on Clean Energy and Climate Change; and the China-ASEAN cooperation framework agreement places a strong emphasis on renewable energy. At the same time, renewable energy is the most practical technological choice for China to reduce its GHG emissions. More than 70% of the Clean Development Mechanism (CDM) projects approved by the Chinese government are renewable energy projects. As such, China's development of renewable energy is having an active impact on its energy security, GHG emission reduction, and global environmental protection.

Table 1 2006 China Renewable Energy Development and Utilization

	Installation		Annual Production		Standard coal equivalent (10 thousand ton/year)
1、Power Generation	**13001**	10MW	**4018**	100GWh	**15270.6**
Hydro Power	12500		3900		14820
Grid-Connected Wind Power	259.33		51.9		197
Small Off-Grid Wind Power	7	(350000 units)	0.7		3
Solar Power	8		1.0		4
Biomass Power	224		63.9		242.8
Bagasse power generation	170		37.4		142.1
Agricultural and Forestry waste power generation	5		2.0		7.6
Biogas power generation	5		2.5		9.5
MSW power generation	40		20.0		76.0
Landfill Gas power generation	4		2.0		7.6
Geothermal power generation	2.5		1.0		3.8
2、Gas Supply			**100**	100 million m^3	**712**
Household biogas	2200		81		577
Large-sized poultry and animal biogas	2000		4		28
Industrial waste water biogas	800		15		107
3、Heat Supply					**3850.3**
SWH(Solar Water Heater)	90000	10 thousand m^2			3600
Solar Cooker	45	10 thousand units			10.3
Geothermal Utilization	3000	10 thousand m^2	6000	10000 Gj	240
Heat Supply	1500	10 thousand m^2			
Heat Water Supply	60	10 thousand households			
4、Fuel					**111**
Biomass Briquette					
Alcohol for Vehicle	100	10 thousand ton			100
Bio-oil	8				11
Total					**19943.9**

2 Hydropower

Hydropower is one of the most important renewable energy resources in China. According to the results of 2003 National Hydropower Resource Assessment, China’s total potential capacity of technically exploitable hydropower is 540 GW, with an annual power generation potential of 2470 TWh. The total potential capacity of economically feasible hydropower is 400 GW, with an annual power generation potential of 1750 TWh. These hydropower resources are distributed mainly in the nation’s western regions, with 70% of the total located in Southwest China and mainly concentrated in 9 resource-rich rivers. Approximately 60% of the total economically feasible hydropower is characterized by technically exploitable features and sound power transport potential.

As of the end of 2006, the total installed capacity of hydropower in China had reached 129 GW, or 19% of total electricity generating capacity, with an annual power generation of 390 TWh (13% of the total power generation). Small hydropower systems comprise 40 GW of this capacity, with an annual power generation of 140 TWh supplying half of the territory, one third of all the counties and one fourth of the total population with power. Nationwide 653 hydropower primary rural electrification projects have been established, and 400 counties established with initial rural hydropower stations and 400 more electrification projects with main power supply dependent on small hydropower are under construction. China’s hydropower exploration, design, construction, installation and equipment manufacturing levels have reached international standards and have formed a complete industry system.

According to China’s Medium and Long-term Development Plan for Renewable Energy, by 2020 China installed hydropower capacity will reach 300GW, with small hydropower making up 75 GW of the total and comprising 75% of the total exploitable hydropower capacity. This level will put China’s hydropower industry on par with developed countries. By 2030 China’s hydropower resources will be almost entirely deployed, with total installed capacity equal to 350 GW and generation of 1500TWh per year. At this time hydropower will be a core source for China’s energy supply.

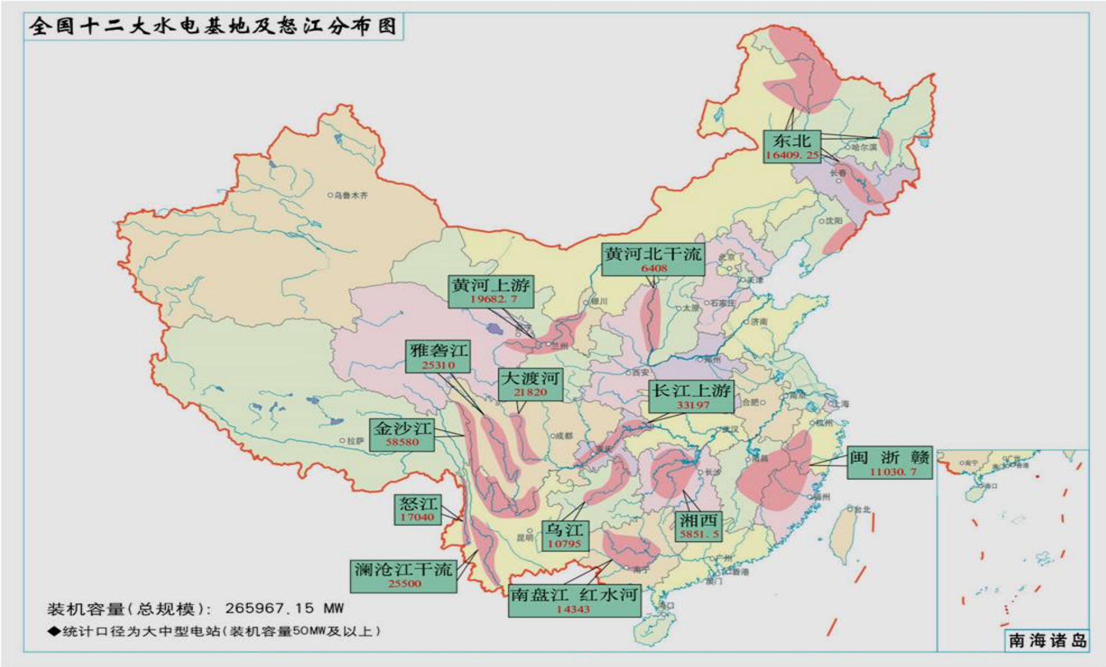

FIGURE 1 THE DISTRIBUTION OF CHINA TOP 12 HYDRO POWER STATIONS AND NU RIVER

3 Biomass

Biomass utilization refers to the in-depth exploitation and recycling of the chemical energy stored in plants and material resources through biomass conversion technology to conduct detoxifying and recycling treatments. In this sector agricultural and forestry residues as well as some environment pollutants (such as animal dung, forestry residues, and organic wastes, etc.) are used as feedstock. Biomass also refers to developing energy plants in marginal lands, saline lands, and aqueous areas to promote the absorption and storage of solar energy by the soils and water. Developing biomass can (i) promote economic development in rural areas, (ii) enhance rural incomes, (iii) accelerate industrialization of agriculture and small & medium town construction, (iv) enable the transfer of surplus labor, and (v) reduce rural-urban disparity in China. China's biomass industry is very promising due to its close relation to energy, the environment and the important issues of agriculture, rural areas, and rural residents. However, biomass has yet to become cost-competitive with fossil fuels. With continued improvement and cost reduction of biomass technology, along with the ever-rising price of fossil energy, biomass will be more fully deployed.

3.1 Resources

The sources of biomass feedstock vary widely. According to production methods and sources, there are two major types of biomass resources: one is the various biomass wastes produced in industry, agriculture processes, and daily life, including agricultural residues, forestry residues, municipal solid waste and organic wastes; the other is human-cultivated biomass resources such as various types of energy crops and energy forests, etc.

3.1.1 Agricultural residues

At present, agricultural residues are a relatively dependable source of biomass feedstock in China. The amount of available agricultural residues mainly depends on crop yields and the collection coefficient. It also depends on proportion of straw returned to the soil as fertilizer (about 15%), used for feed (about 28%), and used as raw material in industry (about 3.29%). With China's current levels of grain production, about 681 million tons of agricultural residues are produced annually. About 546 million tons of these residues are recoverable for further use. Excluding the amount used for the other purposes described above, the amount of agricultural residues available for energy use is about 290 million tons. However, since about one half of crop residues are used through direct combustion in rural life, the actual amount of agricultural residues available to be used as biomass feedstock is about 138 million tons, or 69 million tce. On the one hand, in the long run the amount of agricultural residue produced will increase as the population grows; on the other, as rural life becomes increasingly modernized, the utilization of agricultural residues as a modern energy resource will gradually increase. Use of agricultural residues as modern energy resources is growing at the annual rate of at least 1-3%. After 2030, the amount of agricultural residues that can be effectively used as modern energy resources will be about 400-500 million tons, or 200-300 million tce, an increase of 140-240 million tce from today's levels.

3.1.2 Forest residues

Forest residues that can be used for biomass energy mainly include: logging residues; residue from lumber processing; pruning residues produced in various woodlands (including firewood forests, timber stands, protection forests, shrubbery, and open woodlands); and residues produced from pruning trees beside farmland, roads, villages, and rivers. At this point, given the annual logging quotas established by the 10^{th} and 11^{th} Five Year Plans, the combined total of log harvesting residues plus lumber processing residues is about 74.64-80.56 million tons, or 42.55-45.92 million tce. According to the different firewood harvest and production coefficients in different regions and woodlands national firewood production is 52.393 million tons per year. Excluding firewood forests, this total comes to about 48.1262 million tons. Thus, the usable amount of current logging and lumber processing residues is about

77.60 million tons, or 44.23 million tce, and that of other forest residues is 48.13 million tons, equal to 27.43 million tce. In total, there are about 125 million tons (63 million tce) of usable forestry residues. The amount of forest residues available is likely to rise gradually in the future as total forest coverage spreads.

3.1.3 Animal dung

Animal dung that can be used as biomass fuel comes mainly from cattle, hogs and chicken. The effectively available amount of dung can be estimated based on amounts of livestock on hand in various stages as well as dung production per day. Based on this, the current practical amount of animal dung is about 1.467 billion tons and the available amount is around 1.023 billion tons. In the Stockbreeding Development Plan, it is estimated that the total amount of animal dung in 2010 and 2020 will reach 2.5 billion tons and 4.0 billion tons, respectively, and the available amount will be equal to 120 million tce and 160 million tce, respectively. But due to complicated components of animal dung and its high proportion of water, the energy efficiency of animal dung is relatively low; as such, its potential as an energy source depends on its utilization ration and conversion efficiency.

3.1.4 Industrial organic wastes

A lot of organic wastes are produced as byproducts of agriculture and food processing. For example, grain, food, sugar, and paper production and alcohol distilling result in many organic waste residues and waste water. Industrial waste can be used for compost, combustion and anaerobic fermentation and others purposes. Biogas production by anaerobic fermentation is the most widely used organic waste water treatment. China produces an estimated 50 billion cubic meters of biogas (39 million tce) out of organic wastes from agricultural product processing. Industrial organic waste production will increase with economic development.

3.1.5 Municipal solid waste (MSW)

There are some organic substances in municipal solid waste which can be used as biomass feedstock. In 2006, China had a total of more than 150 million tons of municipal solid waste clearance. Today's methods for treatment of municipal solid waste include sanitary landfills, composting, and incineration technology. More than 80% of MSW is treated through the sanitary landfill method. In the future, power generation with gas produced in landfills or by direct combustion will be the most effective use of MSW in most urban areas. At present, heat value per unit of MSW in China is about 4.18 MJ/kg and the amount of MSW clearance in 2006 was equal to 25 million tce. An estimated 10% of MSW can be used as fuel, producing annually about

2.5 million tce of energy. With continued urbanization and rapid improvements in living standards of municipal residents, the amount of MSW available for fuel is likely to increase quickly.

3.1.6 Animal and plants oil wastes

Oil wastes include edible oil waste produced in the cereal and oil industries as well as oily biomass wastes produced from such oils as cottonseed. In China, 18 million tons of edible oil is consumed every year and millions of tons oil wastes are produced in the process. In recent years, some domestic Chinese enterprises have started to collect oil wastes as raw material to produce biodiesel, producing around 50-100 thousand tons of biodiesel every year. If a comprehensive system for oil waste collection becomes widely established in our country, the oil waste collected can be used to produce 1 million tons of biodiesel every year. Moreover, 4.86 million tons of cotton and 9 millions tons of cottonseed are produced annually in China and in the course of production 1.60 millions tons oil are wasted. It is estimated that every year around 1 million tons of this cottonseed oil can be collected and used to produce biodiesel. Therefore, there are about 2 million tons of oil wastes immediately available to be used to scale up biodiesel development.

3.1.7 Marginal lands

Marginal lands refer to infertile lands that have low exploitation value under current conditions and are not applicable for habitation and construction. For the purpose of biomass scale up development, China should use marginal lands to plant energy crops and energy forests as much as possible to avoid occupying cultivated lands. Combining previous studies on marginal lands, preliminary estimates are that China has 32-76 million hectares of marginal lands (maximum), composed of 7.34-9.37 million hectares backup farmlands (for energy crops), 8.66 million hectares of farmlands limited by harsh winters, 16.0-57.04 million hectares of backup woodlands (for energy forests), and an existing 3.43 million hectares of oil-yielding trees (see fig.2).

The actual proportion of marginal lands which can be used for energy purposes is not yet certain because different crops and plants have different specific requirements for soil nutrients, water and climate. Extensive further investigation and assessment of marginal lands will be warranted before they can be effectively used for energy plants.

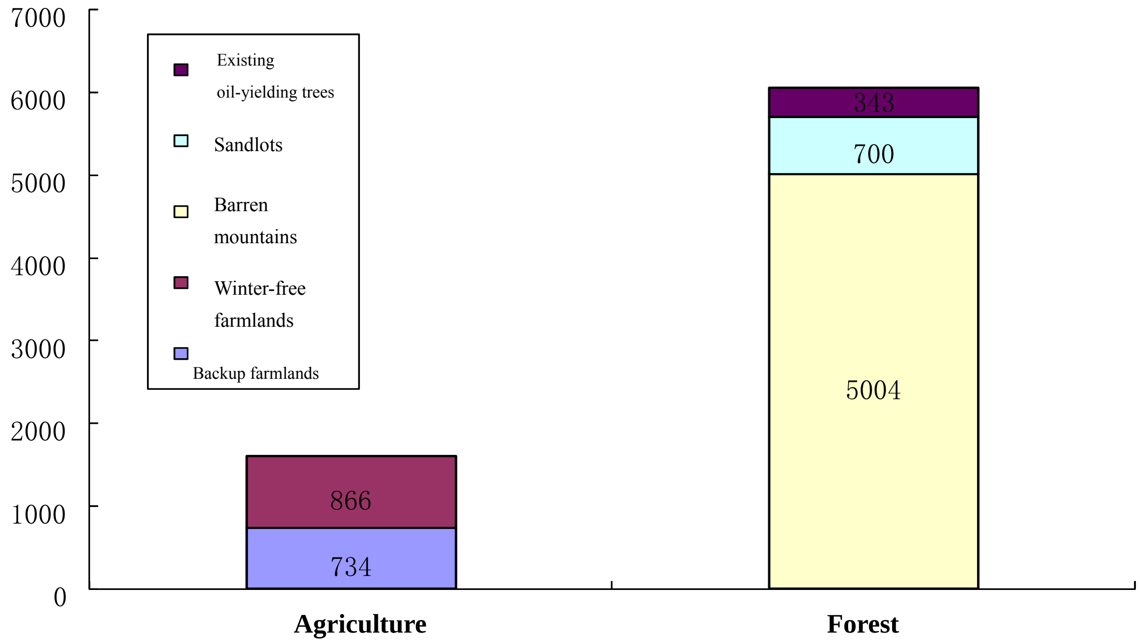

FIGURE 2 VARIOUS BACKUP LANDS RESOURCES DISTRIBUTION

3.1.8 Energy crops

In near future, the energy crops with the most development potential are mainly sweet sorghum, cassava and sweet potato with rich starch and saccharine which can be used for bio-ethanol production, and rapeseed that can be used for biodiesel production. If 80% of farmable marginal lands are used, they will have the potential to produce 34 million tce of biomass feedstock annually, all of which could be used for liquid bio-fuel development.

3.1.9 Energy forest

Energy forests are mainly divided into two kinds based on their use as energy: wood energy forests and oil energy forest. The former mainly includes shrubbery and firewood forests which can be used for power generation and biomass pellet production. Oil energy forests, on the other hand, can provide plant oil as raw material for bio-fuel production. According relevant studies, Jatropha curcas L., Pistaciachinesis Bunge, Xanthocerassorbifolia, and Cornus wisoniana are the most widely distributed trees due to their high adaptability. They can be planted in barren areas such as arid mountains and hills or sandy areas for bio-fuel scale up projects.

As stated in the Report on Forest Resources (2005) by the State Forestry Administration, China has 3.03 millions hectares of firewood forests (2.255 million of natural firewood forests and 0.48 million of planted forests), 3.43 millions hectares of oil-yielding trees, and 45.30 million hectares of shrubbery. The areas of shrubbery in 7 provinces in the west of China account for 69% of the national level. At present, China is actively devoted to exploiting marginal lands or reconstructing existing woodlands for energy forest development. The State Forestry Administration estimates that China will have 13 million hectares of energy forests cultivated or developed by 2020, including 8.90 million hectares of wood energy forests and more than 4.10 million hectares of oil energy forests. These can produce 54 million tons (35.0 millions tce) of dry matter annually, enabling the production of 6.70 million tons of bio-fuel. If 80% of the backup woodlands and existing oil-yielding trees are reconstructed or rebuilt to develop energy forests, there will be an additional 132 millions tce of biofuel produced each year.

Biomass feedstock in China has the following major characteristics: (1) the various biomass resources are relatively rich, giving biomass strong potential to be used as a clean and efficient energy source; (2) energy crops and forests have a definite base in China and the potential to be scaled up; (3) the protection of China's farmlands and ecology is imperative, and to a reasonable extent it is necessary to exploit marginal lands for energy crops and energy forest development.

Summing up the aforementioned types of biomass feedstock, China presently has 280 million tce of utilizable biomass resources. All of these types are wastes from various sectors, and they can be used mainly as household fuel through power generation and biogas production. As China's society and economy develop, the potential of various biomass resources will continually grow. Biomass potential is expected to reach 450 million tce by 2020 and 640 million tce by 2030. In addition, the equivalent of 168 million tce in biomass resources can be added by exploiting 80% of various applicable marginal lands for energy crops/forests. About 34 million tce of these additional biomass resources can be used to produce liquid fuels such as bio-ethanol and bio-fuel; the other cellulose wood biomass resources come to around 134 million tce and can be used for power generation, to produce biomass pellets or cellulose ethanol, and to synthesize fuel when feasible. In sum, after 2030 there will be an estimated 800 million tce biomass resources in China. See Table two for growth trends and proportions of biomass resources in various stages.

Table 2 Potential of available biomass resources

(100 million tce)

	2006	2010	2020	2030	Remarks
Agricultural residues	0.69	0.88	1.43	2.34	Practical amount will reach millions tons
Forestry residues	0.63	0.71	0.91	1.16	Computed with 2.5% growth annually
Animal dung	1.07	1.21	1.55	1.98	Computed with 2.5% growth annually
Industrial organic wastes	0.39	0.44	0.57	0.73	Computed with 2.5% growth annually
MSW	0.025	0.03	0.07	0.15	Computed with 10% used and 8% growth annually
Energy crops	-	0.04	0.25	0.34	Exploitation ratio of backup farmlands and winter-free farm lands will reach 10%, 50% and 80% by 2010, 2020 and 2030, Respectively.
Energy forest	-	0.05	0.82	1.32	Exploitation ratio of backup woodlands and existing energy forests will reach 3%, 50% and 80% by 2010, 2020 and 2030, respectively.
Total	**2.8**	**3.4**	**5.6**	**8.0**	

3.2 Industry characteristics

The biomass sector in China has the following general characteristics: (i) the various biomass resources are relatively rich; (ii) biomass has strong potential to be used as a clean and efficient energy source; (iii) energy crops and forests have a definite base in China and the potential to be further scaled up. In recent years, enterprises developing biomass have conducted comprehensive studies on agricultural residue conversion and utilization. Some technological progress has been made in such areas as biomass pellets, liquid bio-fuel, biomass gasification power generation, sweet sorghum cultivation and bio-ethanol production.

Biomass power technology was listed as one of the key development priorities for alternative energy in China's 10th Five-year Plan and has been listed in the "863 Plan" (National High-tech Development Plan). In this plan, 4MW research-demonstration projects using biomass gasification technology have been constructed; bio-ethanol (from sweet sorghum stem) industrial-demonstration projects have been set up which will have an annual yield of 5000 tons; technology for making bio-ethanol from waste cellulose has entered a pilot phase with an annual output of 600 tons; and biomass pyrolysis liquefaction technology has also entered a pilot phase with an annual output of 300 tons crude biodiesel. The above projects each possess independent intellectual property rights. For the time being, these projects have all been checked and approved by the Science and Technology Ministry. Meanwhile, innovative research and studies for exploratory purposes have been done on technologies for biodiesel, vegetable oil, energy plantation, and biomass fast pyrolysis. In addition, biomass power technology is again noted as one of the key development priorities for alternative energy in the 11th Five-year Plan and remains in the "863 Plan" list.

3.3 Development Status of Biomass Industry

Some new features have appeared as China's biomass develops: comprehensive biomass utilization projects have been supported and widely promoted as part of the implementation of the "Building a New Socialist Countryside" policy. Biomass gasification, gasification power generation and biomass fuel molding industries are developing steadily, enabling significant progress in biomass liquid fuel industrialization.

3.3.1 Direct Combustion and Power Generation

Direct Combustion Technologies:

Direct combustion technologies basically consist of biomass stove burning, biomass boiler burning, waste incineration and dense biomass fuel pellet combustion. Motivated by the implementation of the "Building a New Socialist Countryside" program and benefiting from the rising prices of crude oil and coal, the biomass fuel molding industry gradually is gradually regaining its growth. By the end of 2006, China had 25 registered straw molding factories nationwide.

Power Generation Technologies:

Small scale biomass power generation through combustion has been successfully commercialized. A number of sugar refinery factories in south China generate power from bagasse. There are 380 small scale power generation facilities in Guangdong and

Guangxi provinces with installed capacity amounting to 800 MW, and Yunnan province has similar power generation facilities. China is now preparing straw and husk direct combustion power generation and biomass-coal co-firing power generation demonstration projects using European technologies. So far feasibility studies for the projects have been completed. By the end of 2006, the total installed capacity of biomass power had reached 2200 MW, of which 1700 MW is from bagasse CHP plants and 500 MW is from agriculture residues such as straw and husks, forest residues, industrial and agricultural methane, garbage direct combustion and landfill gas power generation.

Related price regulations have been enforced since 2006, guaranteeing a price subsidy of 0.25 RMB/kWh for newly built biomass power projects for duration of 15 years. The policy has attracted investment in the biomass industry, and many power generation projects using various agriculture and forest residues have been initiated since 2006. The most widely used biomass power generation technologies in China are direct combustion and gasification. In 2006, 39 biomass direct combustion power generation projects with a total installed capacity of 1284 MW were checked and approved by either the NDRC or provincial DRCs, amounting to total investment of 10.03 billion RMB. As of the end of 2006, 54 MW out of the planned 1284 MW already started operation. In the same year 30 MW biomass gasification and landfill gas power generation projects started operation, and similar projects with planned capacity of 90 MW were under construction. The newly built biomass power generation projects mainly use crop stocks and straw as fuel and adopt direct combustion technology (e.g. Straw Generating Project in Shandong Shan Xian County). In addition, pilot projects had been built for the demonstration of straw (-coal co-firing generation projects (e.g. Shandong Zaozhuang Shiliquan Power Plants) and co-generation of heat and power from biomass (e.g. Naimanlin Forestry Biomass CHP Demonstration Projects in Tongliao City of Inner Mongolia). Dramatic progress had also been made in the design and development of biomass power generation facilities. In 2006, Jiangsu Suqian Straw Direct Combustion Power Generation Project was built and began operation using China's first self-developed, IP-protected, locally made facilities.

3.3.2 Biomass Pyrolysis

Biomass pyrolysis technology is similar to coal processing technology. It makes gas, charcoal, wood tar and wood vinegar products from straw, branches and leaves, grass, sawdust, husks and seeds through air-isolated pyrolysis. After purification, with a heat value of 15 MJ/m^3, the gas produced meets the standards for town-level manufactured gas and an ideal fuel for household cooking. This charcoal product is even better than coal in terms of heat value and purification level. Biomass pyrolysis technology developed by Dalian City Design and Research Institute of Environmental Science has been applied in comprehensive utilization of agricultural residues as well as to supply cooking fuel for village households. Put into practice, this technology brings positive economic, environment and social benefits.

The heat value of biomass pyrolysis's liquid product is about 17 MJ/kg. At this point in time, international utilization of biomass pyrolysis technology has yet to reach industrial application. A series of theoretical and experimental studies have been done on biomass pyrolysis by Shandong Polytechnic University, Guangzhou Institute of Energy Conversion, Shenyang Agricultural University, Zhejiang University and East China University of Science and Technology, among others. Preparation and construction for the pilot phase of biomass pyrolysis technology demonstration projects have been listed in the "863 Plan" in the 10th Five-year Plan.

3.3.3 Development and Utilization of Biogas

Biogas utilization technology, particularly for household use, is basically mature in China and has several decades of history. Since 2003, construction of biogas projects for rural households use had been included in the National Bond Projects and over 1 billion RMB every year is invested into this field from China's central funds. Promoted by favorable government policies, household use of biogas has been commercialized and gradually become a large scale industry. Beginning in 2000, large and medium scale biogas projects based on livestock farms, food processing factories, breweries and city sewage treatment plants also started to develop. By the end of 2006, throughout China, there were 22 million biogas pools for rural household use, 140,000 sewage purification biogas pools, 2600 large and medium biogas projects based on livestock farms and industrial wastewater. Annually, these can supply approximately 9 billion m^3 of biogas to nearly 80 million rural people for their daily fuels needs.

With the continuous development and improvement of biogas technology, China's household biogas systems have for the most part attained specialized standards of construction and production. Most regions have set up agencies to provide quality technical maintenance service for biogas systems. As more and more large and medium scale biogas projects are constructed, the technology matures and professional design and construction teams become available. At the same time, service systems in the biogas field have been standardized. This means that biogas technology is ready to be scaled up. Rural household biogas systems are basically comprised of two parts: construction of a biogas pool and integration with pigsties, toilets and kitchens (called "one pool three integrations" systems). Design and construction of these systems must consider the “one pool three integrations” as a whole system from the beginning. Biogas projects based on livestock farms (or a group of farms) should be planned and constructed in association with nearby farms, farmlands, and fish ponds to achieve agricultural cycle development. In addition to supplying energy for the nearby farms and residents, these gas projects should also make full use of biogas slurry and residue to develop eco-agriculture and promote production of pollution-free agricultural products. This not only enables livestock waste to be utilized as resource for energy but is also good to the environment.

3.3.4 Biomass Fuel Molding

Biomass fuel molding makes biomass fuel pellets or strips from loose straw, sawdust and husks through compression, and with further processing the biomass fuel pellets or strips can be transformed to charcoal. There are 3 major types of biomass molding equipment: screw compression, piston ramjet propulsion and ring-shape roller biomass molding machines. At this point in time the screw compression molding machine is the most widely-used biomass molding technology in China. By the end of 2006, there were 25 straw molding factories and stations throughout China. Currently pellets, strips and block-shaped biomass fuels can be made through the molding process; however, conventional molding methods are usually energy-intensive, and the equipment suffers from quick wear and short lifetime. These problems need to be resolved through technology innovation to improve energy efficiency.

3.3.5 Biomass Gasification and Power Generation

Multiple types of fixed-bed and fluid-bed small-scale gasification facilities have been developed in China. These facilities can use straw, sawdust, husks and branches as fuel to produce gas with a heat value of 4 to 10Mj/m^3. So far, more than 800 such facilities are used to dry wood and agriculture products while over 600 facilities are used in village-level district gas supply. All these facilities combined have an annual yield of 20 million m^3 biogas. There are more than 20 biomass gasification power generation systems with MW-scale capacity. During the 10th Five-year Plan, a 4 MW biomass gasification power generation demonstration project was supported under the National “863 Plan”.

The Guangzhou Institute of Energy Conversion (part of the Chinese Academy of Sciences, hereafter referred to as GIEC) has developed a new technology for biomass gasification power generation. During the 9th Five-year Plan, the first MW-scale husks-fueled biomass gasification power generation system was set up in Putian (Fujian province); the first sawdust-fueled biomass gasification power generation system was established in the Hainan Sanya Timber Mill; a straw-fueled biomass gasification power generation demonstration system was constructed in Handan (Hebei province). The above 3 systems all use the gasification technology developed by GIEC. In the near future the provincial agriculture bureau in Heilongjiang province will establish 20 gasification power generation systems which use agricultural residues such as husks and straw as fuel and apply GIEC's technology for gasification. Investment in this new project is estimated at over 40 million RMB. Consuming about 0.1 million tons of agricultural residues yearly, this project's annual energy output will reach 75 million kWh upon completion.

3.3.6 Biological Liquid Fuel

Fuel Ethanol

Fuel ethanol technology uses fermentation to make ethanol from crops which have high sugar and starch content such as sugar cane, corn, wheat and sorghum. This technology is increasingly mature and is beginning to be utilized on a large scale. The technology currently has two forms: one is to first make sugar from cellulose hydrolysis and then convert it to ethanol; the other is to get ethanol from xylose through transgenic yeast fermentation.

Promoting the use of ethanol fuel in vehicles is another strategic measure taken by the Chinese government. Ethanol fuel promotion is one means of developing alternatives to fossil fuel and can help China restructure the composition of its energy supply. Ethanol fuel will also help to avoid groundwater pollution from methyl tert-butyl ether (MTBE) and mitigate emissions of carbon dioxide and hydrocarbons from automobiles.

China has a variety of materials with which to make ethanol: sugar cane and cassava in south China, sweet potatoes in the inland provinces, and corn in north China can all be used as resources for making ethanol. In recent years, experiments around the country on "hybrid sweet sorghum" have resulted in a high-yield, high-sugar-content species whose stem sap has proven to be quality raw material for ethanol production. In 2003, enough sweet sorghum stem sap was supplied to produce 5000 tons of ethanol. In the 10th Five-year Plan, and supported by the National "863 Plan", technology for making ethanol from sweet sorghum stem sap and cellulose residues was successfully developed, and experiments and pilot phases for this technology have been accomplished. A demonstration project using this technology has an annual yield of 5000 tons ethanol from sweet sorghum stem sap. In addition, equipments and facilities for a pilot phase ethanol system (from cellulose residues) are in place, and will have an annual yield of 600 tons.

China began to research and develop fuel ethanol during the 10th Five-year Plan. Fuel ethanol production facilities using aged corn as feedstock have been established and have a total annual yield of 1.02 million tons. Pilot fuel ethanol stations for vehicles have also been set up in 9 provinces in mid and north China. By the end of 2006, 1.02 million tons of fuel ethanol had been supplied by the 4 largest fuel ethanol companies in China as required by national planning. The ethanol produced is supplied through the traditional oil distribution channels to enlarge the capacity of the Pilot Fuel Ethanol Stations throughout Heilongjiang, Jilin, Liaoning, Henan and Anhui provinces, and in parts of Hubei, Jiangsu, Hebei and Shandong provinces. For the time being, closed operation of vehicle-use ethanol-gasoline supply has been fully realized in Heilongjiang, Jilin, Liaoning, Henan and Anhui provinces. Hubei province formally started the same kind of closed operation on December 1st of 2006. Shandong province has 7 pilot fuel ethanol stations in Ji'nan, Zaozhuang, Tai'an, Ji'ning, Linyi, Liaocheng and Heze.

Biodiesel

Biodiesel production technology is basically mature. Major technical methods of biodiesel production include chemical, bio-enzyme and supercritical. Research in China has mainly focused on making biodiesel from oil plants. Development of biodiesel technology was also listed in the National "863 Plan" by the Science and Technology Ministry during the 10th Five-year Plan. Supported by the National "863 Plan", equipment for squeezing sap from Luyu trees has been designed and developed; studies on sap ingredients and fuel features of Luyu trees have been accomplished; and there have been initial successes in research on sap catalytic cracking of Luyu trees.

Most biodiesel producers are private companies, such as Hainan's Zhenghe Bio-energy Company, Sichuan's Gushan Oil Chemical Company, Fujian's Zhuoyue New Energy Development Company and others. Each of these companies established production capacity of 10,000 to 20,000 tons using waste oil from the food industry as the major raw material. These companies also produce high value-added side products additional to biodiesel.

When it comes to scientific R&D, China emphasizes biodiesel production technologies and has done in-depth research on biodiesel materials development. Research bodies involved in this area include: the Chinese Academy of Forestry, the Chinese Academy of Agricultural Sciences, the Plants Research Institutes of the Chinese Academy of Sciences, the Aquatic Plants Research Institutes of the Chinese Academy of Sciences, China Science and Technology University, Sichuan University, China Petroleum University, Beijing Chemical Industry University, Sinopec

Petrochemical Science Institute and others. Material/resources under study include herbal plant oils such as rapeseed oil, soybean oil, and cottonseed oil; woody plant oils such as Chinese pistachio oil, Chinese tallow tree oil, Lvyu trees oil, etc; and aquatic plant oils such as algae oil. Processing methods under study include conventional transesterification with liquid alkali as a catalyst, transesterification with solid alkali as a catalyst, transesterification with an enzyme as a catalyst, and supercritical transesterification.

Because of the limits of China's land resources, scarcity of feedstock is becoming a common obstacle to the development of biomass energy. The main material used for making biodiesel in China is currently cooking oil waste. In 2005, annual biodiesel output was 100,000 tons; in 2006, that number jumped to half a million tons. This resulted in a huge jump in the price of cooking oil waste, from 1800 RMB/ton in the beginning of 2006 to 3000 RMB/ton in the end of the same year. Some biodiesel projects intend to use imported palm oil as material for biodiesel. However, the price of palm oil has risen to 3500 RMB/ton while the market price for biodiesel is only 5000 RMB/ton. This means biodiesel production has lost its cost advantage and cannot develop further without government support.

4 Wind Power

4.1 Resource characteristics and development potential

4.1.1 Rich wind resources

China's wind energy resources are very rich and have great potential for development. Since 2004, according to an NDRC plan for preparing large wind farm projects, the China Meteorological Administration has implemented three nation-wide wind resource assessments. Based on historical data sets between 1971 and 2000 obtained from 2386 weather stations across the country, wind energy resources in China were assessed according to the NDRC's "National Wind Resource Assessment Technical Requirements". The results of these assessments indicate that China's total onshore wind energy capacity measured at 10m height above the ground is theoretically as great as 430 GW, with the technically feasible potential capacity (i.e. regions with average wind energy density larger than 150W/m^2) at around 380 GW on 200,000 km^2 of land. In addition, China has a long coast line with 5～20m deep sea water. Using similar assessment methods to estimate the potential capacity of this area, China's 10m above ground wind energy potential could be as much as 700 GW off shore.

Based on the above assessment, China's long-term wind power capacity has definite potential to reach at least the billion kilowatts-level and wind power is very likely to become be the third largest source of energy in China (after thermal and hydropower).

4.1.2 Wind Energy Resource Distributions

The wind-rich areas in China are concentrated mainly on the southeastern coastal line and nearby islands as well as throughout north China (including the northeast, north, and northwest). In addition, there are several wind energy-rich locations at inland and near offshore areas. China's three "wind belts" are:

1) Coast line and near-coast islands: the 10km wide coastal line belt along the east coast of Shandong, Jiangsu, Shanghai, Zhejiang, Fujian, Guangdong, Guangxi and Hainan provinces has an annual wind power density over 200W/m^2 and wind power density line parallel to the coast line.

2) Northern China wind energy rich belt: 200km belt along the Northeastern three provinces of Liaoning, Jilin and Heilongjiang, Hebei, Inner Mongolia, Gansu, Ningxia and Xinjiang with over 200-300W/m^2 wind power density. Its wind power density reaches a maximum of 500W/m^2 in such areas as Alatawa region and Dabancheng in Xinjiang, Huitengxile and Huiliangteng in Inner Mongolia, and Weichang in Hebei's Chengde.

3) Inland wind energy rich areas: The wind power density is generally no more than 100W/m^2 in inland areas, but there are some wind resource rich areas due to landforms of lakes and special geographic characteristics.

4) Offshore areas with wind potential: along the eastern coastal areas with 5-20m deep sea belt, it is estimated that 700 GW wind energy potential can be utilized based on the assessment (above) of wind resources at 10m height. In addition, these offshore wind areas are close to the major power load centers. As technologies for more cost effective wind farms develop further, the potential offshore wind power capacity will become a vital and sustainable power source.

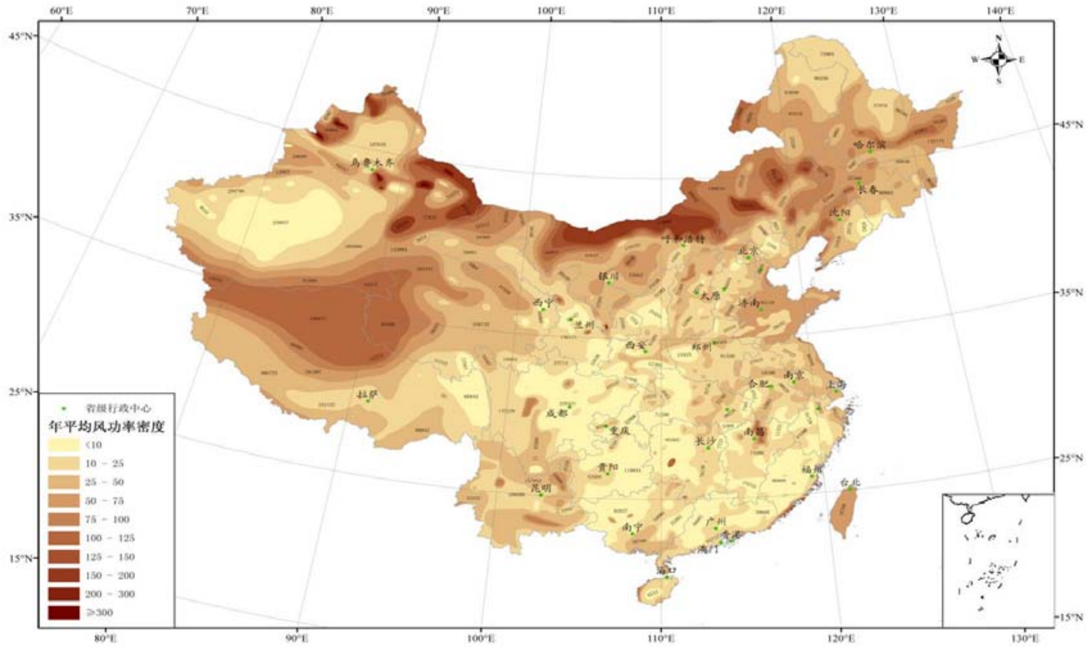

FIGURE 3 CHINA WIND ENERGY RESOURCE DISTRIBUTIONS

Source: China Meteorological Administration.

4.1.3 Wind energy seasonal characteristics and supplement to hydro power

The availability and richness of wind energy can be seasonal: wind is abundant during the spring, autumn and winter, but scarce during summer. But China is also a hydropower-rich country. In south China, the flooding season is generally from March to June, or from April to July, during which precipitation account for 50-60% of annual rainfall; in north China smaller precipitation and uneven rainfall distribution are more typical. Because of the dry season in winter and flooding season in summer, rich wind resources and seasonal water energy can supplement each other. Large-scale wind power systems can offset the shortfalls in hydropower generation during the dry season in spring and winter.

4.1.4 Wind resource distribution unmatched with power load requirement

In China, heavy power loads are concentrated in the coastal provinces where inland wind resources are scarce. And although wind energy resources are plentiful in northern China, the power loads there are comparatively small. This makes cost-effective deployment of wind power very difficult. In addition, the most wind-rich areas in China are very distant from power load centers. As such, improved power grid capacity is necessary to support large scale wind power development.

4.2 Development Status

4.2.1 Off-grid Wind Generator Systems

Targeted users of off-grid standalone wind power systems are farmers in remote areas without networked power supply. Home wind generators are used to provide electricity for lighting and TV. As rural living standards improve and the number of electrical appliances used in rural households increases, required capacity for a single wind turbine unit has increased. The 50W systems are no longer produced and the market for 100W and 150W systems is dwindling; instead, annual production for 200W, 500W and 1000W wind generator systems is increasing, allowing these larger models to account for 80% of annual output.

So far there are 70 off-grid wind power system producers in China, including 35 companies affiliated with universities and institutes, 23 specialized manufacturers and 12 component providers (for batteries, blades, and converter, etc.). Large producer companies include Jiangsu Shenzhou Wind Driven Generator Co. Ltd, Inner Mongolia Longxinbo Wind Power Equipment Manufacturing Company, Inner Mongolia Gutianli Machinary Co. Ltd, Guangzhou Hongying Energy Technology Co. Ltd. In 2006, China produced 30,000 wind generators with single system capacity under 30KW, an increase of 34.4% from 2005, within which the 200W, 300W and 500W systems accounted for 72.5% of the total annual production. In annual output the average single unit capacity of wind turbines was 361W and the total production value was 100 million Yuan.

After more than 20 years of research and development, off-grid wind generator technology and product quality have been greatly improved. During 2005, 5884 systems were exported for US$ 2.83 million. These exports comprised 18% of annual manufacturing output or 27% of annual production value.

4.2.2 Grid-connected Wind Farms

Development of on-grid wind farms in China can be divided into three stages:

Early demonstration stage (1986-1993): During this stage, international grants and loans were used to establish small demonstrative wind farms. The Chinese government also provided financial support for wind farm projects and wind turbine R&D projects.

Sector development stage (1994-2003): In 1994, the Chinese government issued regulations mandating that power grid management authorities should allow wind farms to connect to the grid in nearby power networks and requiring the grid to purchase all the electricity produced by wind farms. It also required that power tariffs should be determined based on generation costs plus loan interest and reasonable profit. The additional higher-than-average electricity tariff should be shared by entire power grid and settled by local utilities. Later the National Planning Commission required power projects to compute wind power price by averaging cost throughout the entire operational duration, allowed wind power projects' loan repayment to be prolonged to 15 years, and reduced the value added tax rate for wind power projects to 8.5%. However, as China's power industry began a reform program to shift toward a competitive market, wind power grew slowly due to its higher cost and unclear incentive policies.

Scale-up and local manufacturing stage (2003-present): In 2004, the NDRC started a "Wind Power Concession Program". This program aims to reduce the on-grid wind power tariff by building large capacity wind farms and achieving scale cost effectiveness. Investors and developers are selected for wind power concession projects through a competitive bidding process in order to improve domestic manufacturing capacity and reduce costs and tariffs.

4.2.3 The Wind Power Concession Program

I. Motivation

To encourage wind power development in China, the former Ministry of Electrical Power determined in 1994 to develop on-grid wind power as a new energy source for China's electrical power sector and improve the country's power infrastructure. To cope with wind power's higher cost, a new tariff policy supporting using loans was adopted. For this policy, tariffs on each wind power project were ratified according to its production cost, profit, and the cost for loan repayment. The cost difference between wind and thermal power is then shared within entire local grid. This policy encouraged rapid wind farm development through expansion of credit to wind farm investors. However, the policy was cut off in 1998 when the national power supply was greater than demand and power sector reform began. According to a new policy, power generation companies were separated from the power grid. Generation companies competed to connect to the grid with tariff offers. Because of no apparent incentive policies for less competitive wind power generators, wind generator installations grew slowly. By the end of 2002, the total national (not including Taiwan hereafter) wind power capacity was only 468 MW. Many problems exist in China's wind farm development, such as the small scale of projects, low domestic wind turbine manufacturing capacity, flexible tariff and investors' limited sources for capital. China's wind power development will be negatively affected unless these problems are solved.

To cope with the above mentioned problems and to promote scaled-up and market oriented wind power development in China, the wind power concession program aims to improve wind power's cost effectiveness through competition between investors. The program is based on borrowing the best international practice in wind power project bidding and experience in other sectors, and was proposed after completion of certain case studies.

II. Operational Mechanism

In 2002, the former National Planning Commission decided to adopt the concession program to develop wind farm projects, and chose Jiangsu and Guangdong provinces (then suffering from power shortages) for piloting.

On December 10, 2002, the NPC approved the Jiangsu Rudong and Guangdong Huilai wind farm concession project proposals, stating that the projects shall select investors by competitive bidding. The selected investors would be responsible for turbine model selection, wind resource assessment, site geological investigation, wind turbine and supporting equipment procurement, and wind turbine installation and testing, as well as the entire investment for power transmission facilities from wind power to grid connection points. It required that no less than 50% of the projects' wind turbines would be locally made.

The concessional operation period has a two-period tariff policy. Before 30000 hours of accumulated wind turbine operation, the tariff is the wind farm execute tariff required by the bidding document; while after the 30000 hours of operation but before the concession is terminated, an average local market on-grid tariff will be implemented. All the electricity produced from the wind farm will be purchased by local utility company. The wind power tariff burden on the power sales shall be shared by the entire provincial utility.

Land acquisition, resettlement and environmental protection activities during wind farm construction, as well as wind farm operation safety and tax rate issues, shall be coordinated by provincial planning commissions.

The NPC shall work together with provincial commission and relevant authorities to entrust a tendering company for the competitive bidding process for concession projects. Bid winners should register in the project location province for a project company and reach a concession agreement and power purchase agreement with utility companies. The concession agreement should be effective for a duration of 25 years. After that the investor company will be responsible for removing all the production facilities except by additional agreement.

National and local incentive policies for wind power will be implemented for the concession projects during their development and operation. In addition to the concession grid-connected power tariff, in case of a big loss of investor profit due to significant national policy changes, the tariff can be adjusted for the projects according to the implementing price incentives.

After a wind farm concession project agreement is signed, the project company should start construction as soon as possible to ensure that the wind farm begins to produce electricity within three years. If a project fails to complete construction in three years without justification, it will be canceled. Investors shall be responsible for all the losses.

From 2002 to 2006, 4 rounds of concession biddings have been implemented and the bidding regulations have been adjusted and improved based on practical experiences. These regulations include: 1) In order to strengthen localization of wind turbines, the requirement for locally made wind turbines has been increased to 70% since the second round bidding. 2) Because of low price competition in the first two biddings, a comprehensive evaluation method has been used since the third bidding, in which the power tariff is no longer the only factor for bidder ranking. Instead, a comprehensive evaluation on bidder capacities, technological proposals, grid-connected tariff and economic soundness will be conducted and ranked according to weighted factors. The power tariff was weighted 40% at the third bidding and reduced to 25% at the fourth bidding.

Another important change at the fourth wind power concession project bidding in 2006 is that wind power equipment manufacturers must bid directly for projects. They can bid as individual investors, or bid jointly with a group of investors as a supplier. Wind turbine manufacturing companies must provide a complete proposal for equipment localization and implementation details.

The wind power concession project bidding is organized by the NDRC. Based upon the proposals received, the NDRC first assess the project preparation, then determines and announces the projects up for bidding. Practical operation of concession bidding is implemented by China International Tendering Co. Ltd and China Hydropower Project Consulting Group, as appointed by the NDRC. The two tendering companies prepare bidding documents and issue the call for bidding invitations in April in major newspapers and on the Internet.

China launched the fifth round of wind power concession projects in 2007 with improved requirements for the biddings. Based on previous experience in bidding projects, several adjustments in bidding requirements have been adopted into the new approach. One of the most important changes is the approach to evaluation of bidding tariffs. In the previous four rounds, selection of investors was biased in favor of the minimum tariff proposals, with the only different being the amount of importance given the tariff in the overall evaluation. In the fifth bidding, a completely different evaluation approach was used: although the grid-connected tariff is still weighted 25%, the closer an offered bidding tariff is to the average value of all the tariff bids, the higher the score a bidder will get. This evaluation approach helps alter some bidders' strategy of offering an unreasonably low bidding price and guiding the biddings to be more rational. Another important adjustment has been to regulate wind turbine manufacturer bidding. The bidding document now requires that wind turbine manufacturers, when being involved in the bidding as supplier, can contract with no more than three bidders for supplying one model of turbines for the same project, whereas in the fourth round of bidding, the supplying contract had to be one to one and exclusive. This adjustment expanded bidders' choice on wind turbines and made the technical proposals more justifiable.

III. Impact

1) The wind farm concession program has demonstrated the Chinese central government's recognition of wind power's importance and the involvement of local government and utility companies in wind power development. For example, by 2005, in Jiangsu province still had zero installed wind power capacity. After three rounds of concession projects, Jiangsu is the biggest wind power installer in China with total installed wind capacity of 1500MW.

2) During the scale-up development stage, the accumulated capacity of the first three round concession bidding was up to 1350MW, of which the largest project was 200WM. In the fourth round bidding, the largest project was 300MW and contract-awarded projects had capacity totaling 1000MW. Total cumulative installations by the end of the fourth stage will be as much as 2350MW.

3) The concession program provided practical experience for formulating the RE Law. The special characteristics of the concession projects, such as commissioned fix tariffs and utility investment in transmission facilities, were adopted in the ordinance.

4) The program's requirement for locally made wind turbines helps protect local manufacturers in the market so that domestic products have the chance to develop. It also helps improve component manufacturing capacity and accelerate R&D and batch production of advanced wind turbine models.

From the four rounds of wind power concession projects between 2003 and 2006, we can see these important measures for China wind power development after the power sector reform by separating generation from the grid. The wind power concession program clarified that wind power does not compete in the general power market; set prices for grid-connected wind power up to a certain amount; and it required utility companies to invest in transmission lines connecting wind farms to substation facilities. It introduced investors' competition mechanism, reduced grid-connected tariffs, and broke up the government monopoly in wind power development. It introduced multiple domestic and foreign investors and proposed the requirement for local wind turbine manufacturing. At the time, when unable to promise a fixed grid-connected wind power tariff and with a lack of local government and utility support for wind power development, the wind power concession program initiated by the central government played an important role in promoting large-scale wind power development. This role must be positively affirmed.

4.2.4 Wind Power Installations

During 2006, mainland China had 2443 newly installed wind turbine systems with total capacity of 1.332 GW. By the end of 2006, a total of 3307 wind turbine systems had been installed at 100 wind farms, in 15 provinces, and with a total installed capacity of 2.6GW. The 2006 accumulated wind turbine installations increased 106% from the 1.26GW of capacity in 2005 (see Figure 6). The estimated grid-connected wind power generation in 2006 was as much as 5.1 billion kilowatts. For China's wind power installation growth since 1986, please see Figure 4.

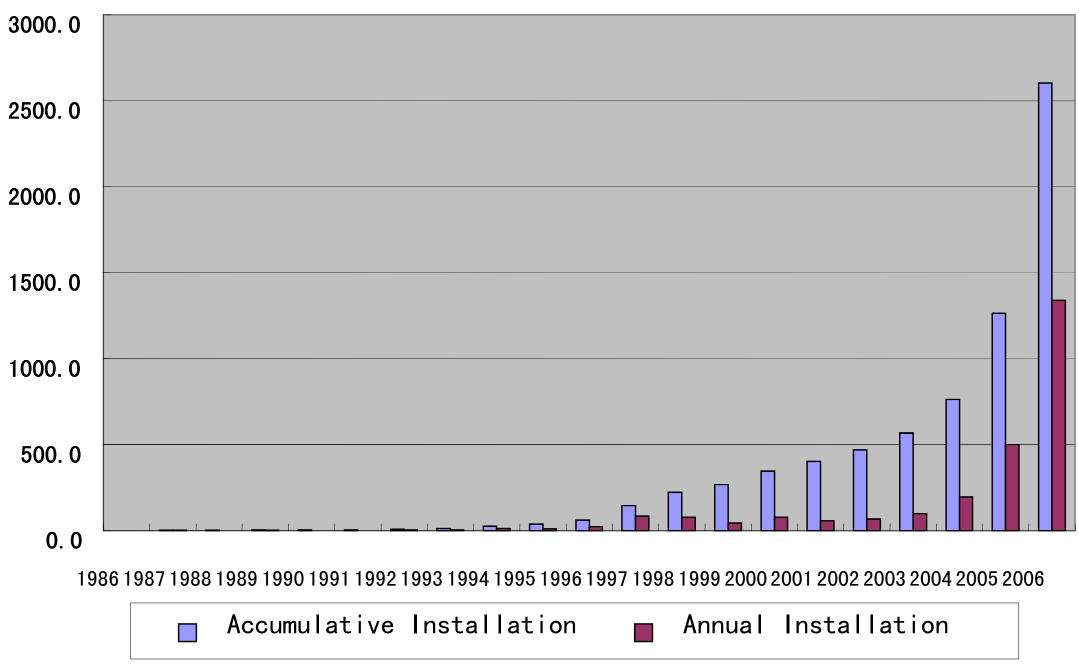

FIGURE 4 WIND POWER INSTALLATION GROWTH IN CHINA（UNIT: MW）

The market share of wind turbine producers in 2006 is as follows: local manufacturers took 45% of the market, among which Xinjiang Jinfeng was the largest contributor, accounting for 33% of the new capacity. Around 80% of the new wind power installations used locally made equipment. Among the foreign suppliers, with total market share of 55%, the largest players were Denmark's Vestas, Spain's Gamesa and America's GE. These companies accounted for 50% of the total new installations and over 90% of imported turbines.

The pattern of installed wind power capacity by province remained relatively unchanged in 2006, but some differences in development became to become apparent. Installations in Inner Mongolia exceeded 500MW, accounting for 1/5 of the total installations nationwide, followed by Hebei, Jilin, Liangning, Guangdong and Xinjiang provinces with installed capacity more than 200MW each. The number of provinces with installations over 100MW grew from 7 in 2005 to 11 in 2006, with Heilongjiang, Shandong, Gansu and Jiangsu provinces adding to the list/rank.

Table 3 Provincial wind power installations in 2006

(Sorted by capacity, Unit: MW)

No.	Province	2005	2006 Newly added	2006 Abandoned	2006Total
1	Inner Mongolia	166.0	343.15		509.2
2	Hebei	108.0	217.5		325.5
3	Jilin	109.0	143.35		252.4
4	Liaoning	127.0	104.8		231.8
5	Guangdong	141.0	67.95		209.0
6	Xinjiang	181.0	25.2		206.2
7	Heilongjiang	57.0	105.0		162.0
8	Ningxia	113.0	46.5		159.5
9	Shandong	84.0	60.75		144.8
10	Gansu	52.0	75.55		127.6
11	Jiangsu		111.0		111.0
12	Fujian	59.0	30.0		89.0
13	Zhejiang	34.0	1.5（1）	3	32.5
14	Shanghai	24.0	0.0		24.0
15	Hainan	9.0	0.0		9.0
	National sum (except HK, Macau and Taiwan)	1264.0	1332.3	3	2593.3

4.2.5 Wind Power Equipment Manufacturing

Research and development on grid-connected wind turbines were conducted for prototypes of 18KW, 30KW, 55KW and 200KW systems as national research projects during the 1980s. However due to slow R&D progress, the turbines were too small and couldn't keep up with market demand for larger systems. Most of the prototypes never got the chance to be further improved into final products. Since the investment in wind turbines themselves accounts for about 70% of the total cost in a wind farm development, locally made systems are greatly needed to reduce total project cost. A popular approach now is to introduce advanced foreign technologies, digest these technologies and gradually build capacity in localization. Through this approach, it is expected that major components of large wind turbines will soon be made in China at 10-20% lower cost compared with similar imported systems.

In 2006, 1.3GW of newly installed capacity set a new record in China's wind power market. Of the total annual installations, Xinjiang Jinfeng contributed 442MW, more than three times the supply in 2005. Jinfeng's 1.2MW DC driven turbine prototype completed installation and began to operate in April 2005. An overseas organization was invited to test the power curves. At the end of 2006, the product passed national final evaluation. It became an important step for Jinxing in product upgrade. Domestic turbine manufacturer Yunda's products grew significantly compared with that in last year, through not many systems were produced. Shenyang University of Technology wind energy institute's project, supported under the Ministry of Science and Technology 863 program, produced a 1MW variable pitch double fed and variable speed wind turbine into its test operation in July 2005. The 1.5MW prototype system was completed in September 2006. Dalian Huarui also made significant progress in 2006 by completing R&D on its 75KW turbine and establishing production capacity for 100 systems per year. It is expected to be a powerful wind turbine supplier in 2007.

Foreign manufacturers continued to dominate China's wind turbine market in 2006, with double pitch, double fed and variable speed turbine technology. Imported MW turbines in 2006 resulted in 730MW of total installed capacity. Turbine systems between 750KW and 2MW in size were manufactured in China by paid technology transfer, joint ventures, joint work with foreign designers, or self R&D. For example, Xinjiang's Jinfeng, Zhejiang's Yunda, Spain's Gomebil (in Tianjin) have batch produced KW-range turbines; Jinfeng, Huide and Huachuang produced MW level prototype systems; Huarui, Dongfang, Accina, Ende (Yinchuan), Indian Suzlon (Tianjin) started to manufacture MW level systems.

Several specialized manufacturers have developed key components required by wind turbine enterprises. For example, the manufactured critical components include generators produced in Yongji, Lanzhou and Zhuzhou generator factories, gear cases in Nanjing, Chongqing and Hangzhou, and blades in Baoding, Shanghai and Tianjin. Over 90% of the components for 600KW and 750KW units are made in China and 70% of 1.5MW generators are locally made.

Chinese manufacturers have mastered technologies for MW level and smaller wind turbines. Major components of these turbines are locally made. This puts China among the top wind turbine manufacturing countries in the world. Production capacity continues to grow and contributes a certain market share. These prototype systems need field testing to find issues needing for further improvement. Domestic wind power equipment manufacturers' market share in China reached 15.3% in 2003. This has successfully broken up imported systems' domination of the market and effectively reduced the prices of imported turbines. Domestic companies' market share increased to 45% in 2006, making a great contribution to China's wind power development. Meanwhile, the continuous growth of domestically produced systems in the market has provided powerful technological support for the future large-scale development of China's wind power industry.

China's wind power development benefits from concession projects. Large-scale development has driven growth in the wind power sector. Industrialization has promoted technology advancement and capacity building. Development of the wind power sector and technology helps to reduce wind farm cost, improve economic returns, and strengthen its competitiveness in the power market.

4.3 Development Objectives

Based on the above analysis and international experience, phase-based targets have been proposed for wind power development in China.

(1) Before 2010, a government support and market driven strategy will focus on relieving three major bottlenecks in China's wind power sector: resource assessment, grid connection and innovation in wind turbine technologies. This steady development strategy will be implemented to lay a solid foundation for future large-scale wind power development.

(2) A comprehensive wind power sector will be developed in China by 2020. The currently planned wind power targets are expected to be surpassed.

(3) Between 2020 and 2030, a mature wind power sector chain will be well established. While continuously expanding domestic power market share, the Chinese

wind power industry will also be actively entering the international market. Wind generated electricity will play a more important role in powering China's economy and social development.

(4) After 2030, China wind power industry will become strong in market competition. Wind power will develop into a mature sector.

5 Solar Energy

5.1 Solar Energy Resource

Based on observation data obtained at 655 national weather stations in the past 30 years and model computation result, China is a solar energy rich country with total annual radiation of about 120-280W/m^2. An isoline with radiation strength of 180W/m^2 stretches from mid Inner Mongolia westward to mid Yunnan along the east side of Tibetan Plateau. This line divides China into two sections: the northwest part with radiation above 180W/m^2, and southeast part with radiation below 180W/m^2 on most land. Annual total solar radiation descends as you move eastward, while the Tibetan Plateau is a stable high solar radiation area. The highest radiation values are observed at Tibetan Yaluzangbu River valley with the maximum value above 280W/m^2. Solar energy resource potential is correlated with geographical latitude, landforms and atmospheric circulation conditions. It is therefore both seasonal and geographical. If we assume that only those areas with radiation strength above 160W/m^2 are feasible to develop for solar power, about one third of China's territory can be considered for potential solar power capacity. China's annual solar energy exceeds 6 billion J /m^2. The total ground-received solar energy each year is equivalent to 1700 billion tce and has great potential for commercial development.

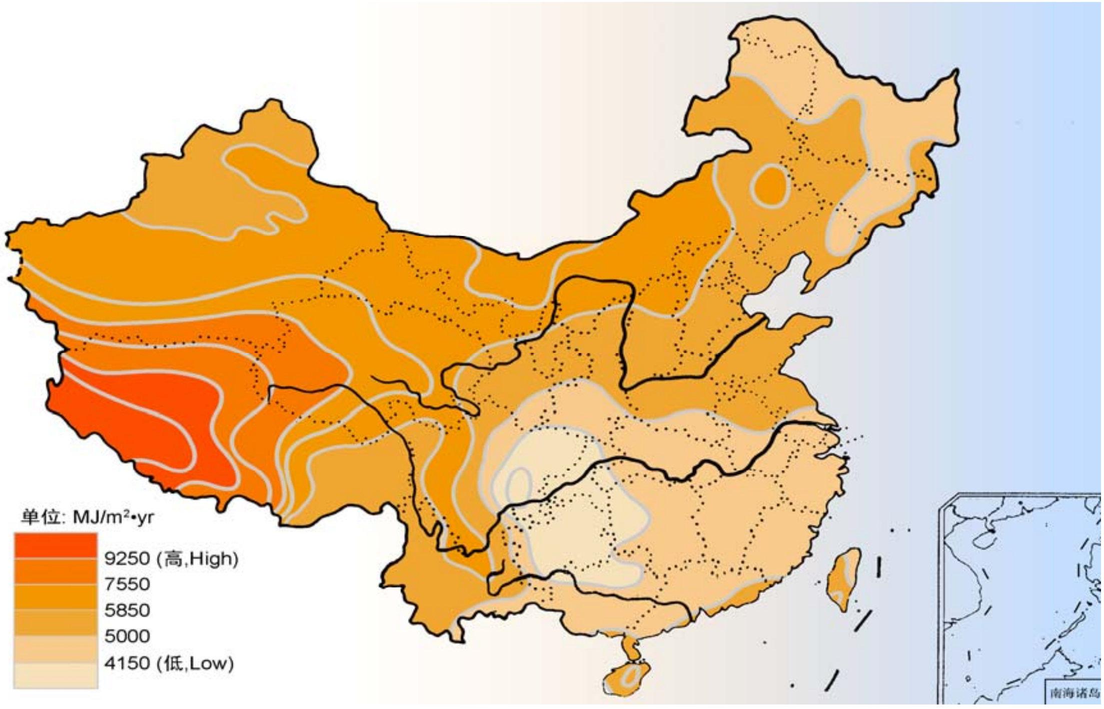

FIGURE 5 CHINA SOLAR ENERGY RESOURCE DISTRIBUTION

Source: China Meteorological Administration

5.2 Solar Photovoltaic

Chinese photovoltaic cell and module production made up about 1% of global output before 2002. But China's photovoltaic industry has developed rapidly since 2004 due to strong demand in the international PV market, especially in Germany and Japan. Annual production of PV cell and components has jumped considerably: every year, China produces 25MW of high purity silicon materials, 580MW of silicon ingots, 500MW of wafers, 1400MW of cells and 1080MW of modules. Chinese solar manufacturers contributed more than 10% to the world photovoltaic market in 2006, ranked 3rd only after Japan and Europe. It is expected that by 2010 China will become one of the largest solar cell manufacturers in the world, with annual production capacity of 1GW.

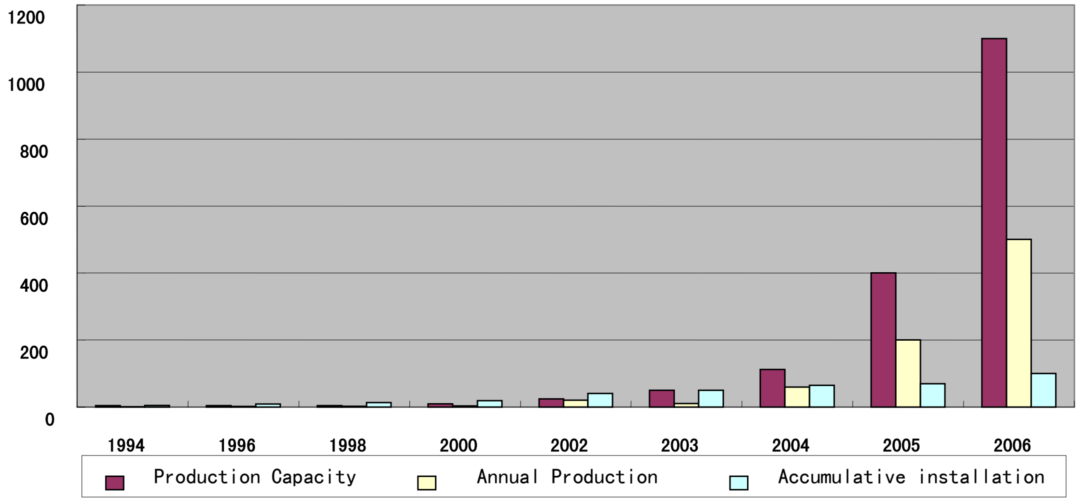

FIGURE 6 CHINA SOLAR CELL MODULE PRODUCTION CAPACITY, ANNUAL OUTPUT AND MARKET CONTRIBUTION（UNIT: MW）

Compared with the fast expanding photovoltaic manufacturing sector, the domestic Chinese photovoltaic market has grown slowly. It is very important to study the situation and develop an aggressive strategy for promoting the development of both the manufacturing sector and the domestic market.

5.2.1 Solar PV Industrial Development

Since entering the new millennium, the Chinese PV industry has developed at a tremendous speed. Particularly since 2004, due to the strong pull of global market demand, the rapidly growing Chinese solar sector has created a complete industrial chain of multi-crystalline silicon materials, silicon ingots/wafers, solar cells, modules, solar PV systems, special materials, special equipment, test equipment, and control systems.

1）Solar grade silicon

Chinese technology in solar grade silicon is still well below the highest international technology standards. Scarce industrial capacity makes the supply of raw material extremely short in China. Before 2005, there is only one company in China producing silicon materials: the Emi Semiconductor Factory with annual production capacity of 100 tons but actual output of only a few tons due to the factories small-scale and low level of technology. The Luoyang Zhonggui Company has established a production line with planned annual capacity of 300 tons using Chinese technologies. This facility started operation in 2005 and produced 240 tons multi-crystalline silicon product in 2006, although some critical technologies are still under research. In addition, the Sichuan Xinguang Silicon has introduced the Simens 1260 ton capacity multi-crystalline silicon production line which is expected to be operational by the end of 2007. Although the technology used is not the world's most advanced, successful production can introduce a thousand tons of new production capacity in China's multi-crystalline silicon industry.

Currently many Chinese companies are planning to establish super pure crystalline silicon production lines with each capacity over 1000 tons each. It is estimated that China will have over 18000 tons crystalline silicon production capacity by 2008.

2）Silicon Ingots and Wafers

China's solar grade silicon ingot/wafer manufacturing has grown at a faster pace since 2003. In 2005, China produced 2386 tons solar grade silicon ingots, including 2086 mono-crystalline silicon and 300 tons multi-crystalline silicon materials. The Jinglong Group, for example, installed 300 mono-crystal furnaces for producing 1126 tons silicon wafers. With total production capacity of 1500-2250 tons, it is one of the largest producers of direct pulling wafers. Baoding Yingli Solar is equipped with 23 polycrystalline growing systems and produced 260 tons of solar silicon rods in 2005. Also in 2005 Jinzhou Huari, Jingsu Shunda, Changzhou Tianhe and Ningbo Jingyuan produced 400, 200, 60, and 40 tons solar silicon ingots respectively. By 2006 Jiangxi's LDK Solar had invested in 100 large poly-crystalline silicon ingot furnaces for 100MW of ingot/wafer production capacity and is one its way to becoming one of the most important Chinese multi-crystalline silicon producers.

3） Solar cells

China's solar cell industry has also developed at a tremendous speed since 2003, with annual growth rates between 100% and 300%. By 2006, there were more than 20 large solar cell manufacturers producing a total of 500MW of solar cell products, including crystalline silicon cells and about 3% non-crystalline silicon cells. Wuxi's Suntech, the largest Chinese solar cell manufacturer, produced 82MW of solar cells, accounting for 56.3% of national output of solar cells or 61.7% of national production of crystalline cells. Other major solar cell producers (as listed in Table 12) include Ningbo Solar, Shenzhen Tuori, Guangdong Quanxin, Shanghai Taiyang, Nanjing Zhongdian and Tianwei Yingli. Within only 3 years, China's contribution to the global solar cell market increased from 1.07% in 2002 to 8% in 2005, and then surpassed 10% in 2006, making China the world's third largest producer after Japan and the EU. Besides expanding capacity in existing facilities, many companies are investing in new solar cell projects. By 2006 China had 1674.5MW annual installed production capacity, including 1629 MW for crystalline silicon and 45.5MW for non-crystalline cells.

4） Solar modules

Solar module coating and manufacturing is developing at the fastest speed in the solar PV sector. It is estimated that there are over 500 solar module producers in China. Products from most of these manufacturers have passed international certification such as TűV and UL. Recent statistics revealed that module bonding capacity reached 1200MW in 2006.

5） Growth of related industries

In addition to the direct solar PV industry, other solar-related industries have also been developing robustly. These industries include solar PV generator system and utilization technology; component manufacturing for solar PV-required controllers, inverters, batteries, electrical system, supporting systems, and cables; equipment manufacturing for mono-crystalline furnaces, cleaning machines, plasma etches, diffuse furnaces, drying ovens, selection machines, semi-auto screen printing machines, layer pressures, laser markers, cell selectors and module test equipment; and specialized material producers for EVA, aluminum plasma and coating glass. These solar related industries have become an important part of the Chinese solar sector and their development has played a critical role in reducing the cost of solar power.

In sum, the Chinese solar PV sector is developing into a specialized, scaled-up and internationalized producer in the global solar market. Wuxi Suntech was ranked as the world's 8th largest solar cell producer with 82MW annual capacity in 2005. After going public in December 2005, it had material supply contracts worth US$ 6 billion and purchased Japan's MSK in 2006. The landmark event demonstrated that the Chinese solar PV sector can compete in the international market. The Jinglong Group produced 1126 tons mono-crystal direct-pulling silicon ingots in 2005 and has become the world largest supplier of this product. Several MW capacity ingot and cell producers emerged in 2006, making the Chinese silicon sector even more specialized, scaled-up, and international. These internationally advanced enterprises are building their capacity for a healthy and mature Chinese PV industry. At the same time, this industrial development has trained an excellent group of entrepreneurs and technical teams in the solar industry, which in turn promotes Chinese solar technology development

5.2.2 Solar PV Market Development

China successfully implemented the "power to the villages" program during 2002-2004, investing a total of 4.7 billion Yuan of special central and local government funds to bring power to 1065 towns and villages in 12 provinces including Inner Mongolia, Qinghai, Xinjiang, Sichuan and Shannxi. These villages received renewable electricity supply systems including PV, PV and wind hybrid and small hydro power stations. Solar PV systems were installed in greatest number, and the 17MW of solar cells installed helped develop the domestic solar photovoltaic market. But because power generated from solar PV cells is more expensive, use of PV cells has grown relatively slowly. By 2006, accumulated solar PV installed generation capacity was 80MW, of which 42% were independent PV power systems installed to supply electricity to remote rural families without grid access. The market for solar in telecom base stations and for PV-related products is growing as well.

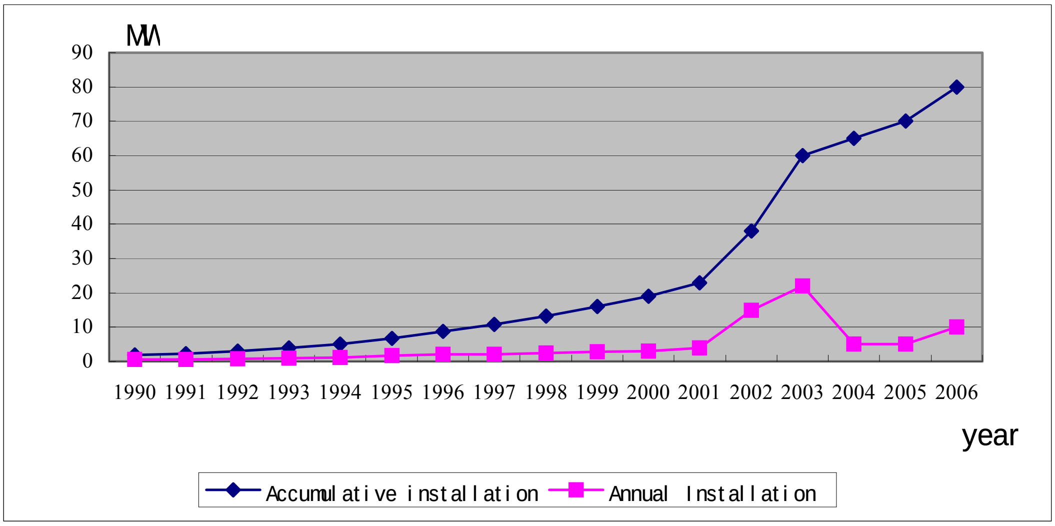

FIGURE 7 DEVELOPMENT TREND OF CHINA SOLAR PV MARKET

From Figure 7 it is clear that although China's solar PV market grew steadily at an annual rate about 17%, this is much slower than the international average of 30-40% during the same period. See Table 4 for market shares of different solar PV applications at the end of 2006. In the overall solar PV market, commercial applications made up 54% of total use (for the communication sector and solar PV products), while 46% were for government-supported installations for rural electricity programs and for grid-connected solar PV generation systems. Grid-connected PV generation only accounted for 2MWp, or 3% of the total solar PV market. This is far behind the international level of about 60% of the solar market going to grid-connected power generation, or 75% of total installed capacity in 2005.

Table 4 China solar PV application market shares be the end of 2006

Market division	Installation (MW)	Market share (%)
Rural electricity	30	43.0
Communication and	28	40.0

industrial applications		
Solar PV products	10	14.0
Grid-connected generation	2	3.0
Total	70	100

5.2.3 Critical Technologies

R&D on solar generation should focus on the critical technologies for reducing cost and improving efficiency, including:

(1) Crystalline silicon solar cell technology

Crystalline silicon cell is still the mainstream of solar cell development. The key Chinese technologies should include: manufacturing cheap solar grade silicon materials, super thin cutting technologies and bonding equipment development, and new generation crystalline silicon cells.

(2） Thin film cell technology

There are two major types of thin film solar cell technologies, i.e. silicon and non-silicon cells. China should be focusing R&D on manufacturing equipment and master equipment, and on developing new thin film cell technology.

(3） Solar power utilization technology

In the Chinese solar generation market, home solar system technology is basically mature, and small independent solar power station technology is improving. Several critical technologies for expanding the market may include: desert solar power station technology, high voltage and low voltage grid-connected solar generation systems and system stabilizing technologies and equipment.

5.3 Solar Thermal

Solar thermal applications mainly include solar water heaters (SWH), solar thermal generation, solar fueled stoves and solar heated houses. Currently solar water heater systems are industrially produced on a large scale in China, as introduced in detail in the following subsections.

5.3.1 Solar Thermal Industry Development

By 2006, 90 million m2 solar water heaters were installed in China. Annual production capacity was nearly 20 million m^2, an increase of 30% from 2005. Actual production in 2006 was 18 million m^2, 20% more than 2005 output. China's production and use of SWH comprises one half of the world's total. The commercialized SWH industry has created a complete supply chain of raw material processing, product R&D, engineering design, and marketing services. Meanwhile it drives related industry development in glass, metal, heat reservation material and vacuum equipment manufacturing and is becoming a fast growing new sector. There are currently more than 1300 SWH manufacturers in China producing on a significant scale. In particular, the Chinese patented vacuum tube technology is internationally advanced. The vacuum tube SWHs are widely used in China, with annual production of over 16 million m^2, comprising 90% of the global market sales. These high quality SWH products are exported to dozens of countries in Asia, Europe and Africa. Table 5 summarizes China's SWH production and installations.

Table 5 China SWH annual production and total installations between 2001 and 2006

Year	Production		Annual growth%	Total installations		Annual growth%
	10^4m^2	MWth		10^4m^2	MWth	
2001	820	5740	28	3200	2240	23
2002	1000	7000	22	4000	28000	25
2003	1200	8400	20	5000	35000	25
2004	1350	9450	12.5	6200	43400	24
2005	1800	10500	11.1	7700	53900	24
2006	2000	12600	20	10000	70000	30

By 2006, China's SWH sector had annually production valued at 20 billion Yuan with annual sales revenue of 30 billion Yuan. Exports of SWH are worth US$ 50 million per year and the sector has provided more than 1 million job opportunities. A complete production chain has been established for glass materials, all-glass collector and water heater unit manufacturing, marketing and servicing, mechanic processing equipment, component production and other supporting industries.

The standardization system for solar thermal has been greatly improved. National and local product quality testing and certification activities have been conducted, making for satisfactory improvements in product quality assurance and market regulations. By the end of 2005, a set of 17 total national SWH standards had been implemented, including national and sector-based technical codes. Two national solar water heater test centers have been established for product testing. In the 2005 survey on home SWH systems by National Quality Inspection Administration, 90.2% of the sampled 61 batch products passed inspection. Also, the SWH product certification procedures were initiated in 2005. By 2006, 21 SWH producers had attained certification of their products' quality.

5.3.2 Solar Thermal Market Development

China's SWH installations make up 60.6% of the world's total capacity. 75.8% of the new SWHs in 2006 were installed in China, making China the world's biggest consumer of SWHs. However because of its huge population, China's per capita SWH installation rates in 2004, 2005 and 2006 were only 48m^2, 57m^2 and 69m^2 per thousand people respectively. This is higher than the global average (38m^2/thousand people in 2004), but far lower than the international best practice.

China is currently a period of rapid economic and social development, and as a result people's demand for bathing water is growing tremendously. The solar water heater sector will keep growing in the expanding market in large Chinese cities due to the following trends: ever-rising prices of conventional energy products, greatly increased demand for hot water, improved environmental awareness among the public, upgraded SWH products and development of building-integrated solar thermal technologies.

6 Additional Renewable Energy Technologies

In addition to hydro, wind, biomass and solar energy, geothermal and ocean energy technologies also have great development potential. As potential new and renewable energy sources, they can be developed for certain specific applications.

6.1 Geothermal Energy

Geothermal energy utilization can be classified into geothermal generation and direct geothermal utilization. Geothermal generation requires high temperature geofluid, generally at 150° or even 200° to be cost effective. China's few high temperature geothermal resources are concentrated in the Tibet and Yunnan's Hengduan mountain range areas. Investigation and development of this resource are mainly in Yangbajing (Tibet) and Tengchong (Yunnan): 88% of China's 32.08MW of installed geothermal generation capacity are at these two sites. Because of the strict technical requirements for geothermal energy sites, China built no new geothermal power stations between 1993 and 2003. The 48.8MW Tengchong geothermal power station started construction in 2004. This new facility will become the second largest geothermal generation project in China.

Comparatively, geothermal direct utilization requires lower temperature of underground hot water so that middle and low temperature geothermal resources can be utilized for heating, greenhouse planting, bathing and medical treatment. China's geothermal resources are of mostly medium and low temperature and can be found in many places. Since the 1990s, use of medium and low temperature geothermal resources has grown at 10% annually. Geothermal heating has been actively developed in northern China in particular for heating and hot water supply. By 2005, total installed geothermal heating areas increased to 30 million m2, providing hot water for about 600,000 homes.

Geothermal heat pump is one of important geothermal direct utilization technologies. It is widely applied as a distributed heat source. The heat pump can use widely available low temperature geothermal sources or reuse discharged geothermal waste water at 30~40° to provide heating service. As a new energy industry, use of geothermal heat pumps has grown rapidly after 2000 in China's large cities. Due to energy resource shortages, heat pump technology is receiving more and more attention and has been applied at office buildings, hotels, and residential buildings, with over 10% annual growth. The geothermal heat pump will be one of the key development areas in the geothermal energy sector and will play an aggressive role in promoting China's low energy building program.

6.2 Ocean Energy

Ocean energy includes tidal energy, wave energy, and ocean current energy. China has constructed 8 tidal power stations. New tidal power technologies are under research and demonstration. In addition, wave energy technology has been under R&D since the 1980s and China has seen significant improvements in wave energy transmission efficiency, wave energy table output and equipment manufacturing. In 2004, a Chinese experimental independent wave power generation system successfully converted the 8kW power unstable fluid pressure energy into a stable electrical power. Later in 2005, the experimental system converted unstable wave energy into stable electricity. By the end of 2005, a 100kW and a 20kW shore-mounted oscillating wave power device and nearly 700 below-1kW smaller wave power devices had been developed in China.

7 Prospect of Renewable Energy Development in China

7.1 Analysis on Development Potential

Renewable energy resources are abundant in China: two-thirds of China's territory enjoys rich solar energy, total solar radiation per unit area of over 5GJ/m^2 that is around 1.7 trillion tce equivalent solar energy absorbed by the earth's surface. Potential national wind power capacity is 3200 GW, with immediately exploitable potential wind capacity estimated at 1000 GW. Based on the experiences of such advanced wind power users as Germany, Spain and Denmark, China's long term wind power capacity may even surpass 3000 GW. The estimated technically exploitable capacity of ocean energy is 400-500 GW. Future reserves of geothermal energy are estimated at 135.3 billion tce, and proven reserves are already at 3.16 billion tce. Existing biomass resources including straw, forest residues, organic MSW, and industrial organic wastes can provide 700 million tce worth of energy and this number could be doubled by improving breeding and extending energy crops. Thus, China has a significant renewable energy resource base and the technological potential to scale-up renewable energy development, thereby ensuring energy supply security for social and economic development in the future.

According to research for China's medium and long-term renewable energy development plan, China can basically rely on conventional energy to meet energy demand for economic development and improvement of living standards until 2020; after 2020, when total energy demand exceeds 3 billion tce, renewable energy's strategic role will become increasingly apparent, and it will be expected to provide up to hundreds to thousands million tce to support national energy supply. In this case, the strategy objectives of renewable energy development are to maximally increase energy supply capacity; to improve energy consumption structure; to diversify the energy supply; and to ensure energy supply security.

The first step will be to install 360 GW renewable energy power generation capacity by 2020, making up 35% of total power generation capacity nationwide. In order to realize this target, China plans to speed up the utilization of hydropower, solar thermal, and geothermal, which have the advantage of competitive markets to allocate resources toward the most effective use. China also plans to promote power generation from wind, biomass and solar energy. The detailed targets are as follows: by 2010, the total installed power generation capacity of small hydropower, wind, biomass power, geothermal power and solar power should reach more than 200 GW, comprising around 30% of power generation capacity nationally. Of this sum, 190 GW will be hydropower, 5GW wind, 5.5GW biomass, and 300 MW solar. By 2020, the total installed power generation capacity of small hydropower, wind, biomass power, geothermal power and solar power will reach more than 360 GW, comprising around 35% of power generation capacity nationally, and made up of 300 GW hydropower, 30GW wind, 30GW biomass, and 1.8GW solar. Meanwhile, China plans to actively develop renewable energy to provide heat and liquid bio fuel, and by 2020, total renewable energy supply capacity will reach 540 million tce.

The second step is to dramatically increase the proportion of renewable energy in total energy consumption. Referring to the experiences of developed countries as a guide for estimates, the proportion of renewable energy in China will reach 30～40% by 2050. To reach this target, China has to have wind energy ranked the third in power generation capacity, then exceed that of nuclear power in thirty years, and then after 2050, with installed capacity of 300-500GW, ranked the second and exceeding hydropower in generating capacity. During the period of 2020 to 2030, hydropower has to be fully developed with installed capacity of 300-350GW by 2030. And by 2050, installed solar water heater capacity has to reach 1 billion m^2, replacing 600 TWh of electricity, and 400GW of peak power generation capacity. By 2040, installed capacity of solar power has to reach 200GW. Meanwhile, China has to develop scaled-up biomass energy, ocean energy, geothermal energy, and other renewable energies to meet the overall objective of optimized energy structure and energy demand in 2050.

Having made efforts to develop renewable energy for more than thirty years, China has achieved some progress; however, there remains a big gap between China's renewable energy development and utilization with that in European countries, the US, Japan, and others. The main technology barriers are: Weak R&D capacity for wind turbine design and manufacture – China has not formed designing and manufacturing capacity based on its own IP, and wind turbine manufacturing so far relies mainly on either technology transfer like production permits, or importing equipment directly. Another barrier is lack of innovation capacity for solar PV manufacturing. This sector also relies on importing key manufacturing equipment and raw material. Also, China has not mastered the key technique of large scale production of liquid bio-fuel from cellulose. Many enterprises and manufacturers developed rapidly but blindly after the RE Law was issued because they entered the market without sufficient understanding or preparation. At present, there are over 40 wind turbine manufacturers in China, which is three times the number of producers in most other countries. However, the production capacity of solar PV modules is only about 50% of the global standard. Liquid bio-fuel production has increased quickly and broadly and requires urgently government implementation of new incentive policies, particularly to resolve the issues of high cost and relatively low market demand.

Renewable energy in China has great potential, but there remains plenty of room for further development. It is impossible to complete the objectives and targets in one night, and instead they require more time and harder work in a gradual development approach. Cooperative efforts are needed from the government, experts, entrepreneurs, and all society as well.

7.2 Background and Tasks

Renewable energy development is a long-term historic mission in China. Maintaining the current campaign of speeding up the establishment of a resource-saving and environmentally-friendly society, the main tasks of renewable energy development in the coming 15 years are:

（1）To increase the proportion of renewable energy in total energy consumption. At present, China is the second largest producer and consumer of energy in the world. As the economy develops and living standards improve, energy demand will increase, as will the pressure of energy production and supply. Relying only on fossil fuel cannot meet the energy demands of concurrent economic, social and environmental development of due to scarcity of petroleum and nature gas resources. Hydropower, biomass, wind and solar energy in China have great potential and already or nearly mature technology. These energy sources have favorable prospects for large scale utilization and development. Increasing the proportion of energy supply that comes from renewable energy by speeding up the development of hydropower, biomass, wind and solar energies is a top priority task for China in order to reduce proportion of coal in total energy consumption.

（2）To resolve the problem of lack of electricity in remote off-grid areas and the shortage of fuel for daily life needs in rural areas. Providing power to those currently without electricity is closely tied to achieving the goal of a moderately well-off society, stabilizing border areas, promoting the unity of all ethnic groups, and improving living standards. Rural areas without electricity are remote, lacking in traditional energy resources, and have lower population density than other areas. Renewable energy utilization and application is the most efficient way to resolve power supply problems in these areas because most traditional energy facilities are not suitable there. Agricultural areas are heavily populated and characterized by backward energy use, low living standards, and damaged ecological environment due to use of forestry and plants as the main energy fuel for daily life. Renewable energy utilization in agricultural areas could supplement traditional fuel, play an active role in improving local production and living conditions, and promote the establishment of a local moderately well-off society as well. Thus, a high priority task for China is to resolve rural power supply issues and improve rural living standards by utilizing renewable energy.

（3）To stimulate a recyclable economy by utilization of organic wastes for energy. A huge volume of organic wastes come from crop and food processing, forestry and timber producing, livestock and breeding, industrial production, and MSW processing. Renewable energy could transfer these organic wastes into energy forms such as electricity, gas, and pellets fuel, etc. This measure is important not only to make full use of waste and produce valuable energy, but also to protect the environment and work to promote a recycling-based economy. Thus, a high priority task for China is to make full use of all kinds of organic wastes for energy to promote recycling-based economic development.

（4）To promote the development of renewable energy industries by scaling up renewable energy technologies utilization. At present, except for a limited number of technologies including hydropower, solar thermal and biogas, most renewable energy technology industries are basically weak and lack the ability to compete in a commercial market. It is a top priority task for China to increase renewable energy technology utilization level and create a comprehensive industrial infrastructure system. By 2010 China will stress the importance of building the policy system and institutional capacity building while it also speeds up renewable energy technology development and utilization so as to set up basic foundational industries favorable for renewable energy development. Between 2010 and 2020, China aims to build up a comprehensive renewable energy industrial system to dramatically reduce renewable energy utilization cost and to facility renewable energy scale-up development. After 2020, renewable energy technology will become a main energy supply option with obvious competitive capabilities in the market.

The overall objectives for China's renewable energy development are: to increase the proportion of renewable energy in total energy consumption, to resolve rural power supply and fuel problems, to stimulate the utilization of organic wastes for energy, and to promote the development of renewable energy industries. The specific objectives are as follows:

（1） By 2010, China will aim to raise the share of renewable energy in total primary energy consumption to 10 percent. By 2020, it will aim to raise this share to 15 percent. This will be achieved 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.

（2） China will also aim to provide electricity to people in remote, off-grid areas and resolve fuel scarcity problems in rural areas through the use of renewable energy, doing so according to local conditions and at the same time effectively protecting the ecological environment. The utilization of organic wastes for energy will be promoted according to the principle of a “recyclable economy” basically eliminating the environmental pollution problems cased by organic wastes.

（3） China will actively promote the development of renewable energy technologies and industries, building up a renewable energy technology innovation system. By 2010, China will basically have achieved the ability to produce domestically the main renewable energy equipment it uses. By 2020, local manufacturing capability based mainly on home-grown IP will be achieved.

7.3 Priority Sectors

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 be as follows:

7.3.1 Hydropower

Hydropower is one of the priority sectors for renewable energy development in China. Based on consideration of the resource distribution, utilization condition, economic development level, and power market demand, the priority drainage areas for hydropower development are Jingsha River, Yalong River, Dadu River, Lancang River, Yellow River, Wu River, and Nu River. Meanwhile, in the areas with rich hydropower potential, the priority is to promote the development of small hydropower in conjunction with the rural county electrification program and the implementation of “Substitution Electricity for Fuel”. Construction on a series of large hydropower stations is planned before 2010. Planned stations have capacity of 1GW and above and include Jingxiluodu and Xiangjiaba stations on Jingsha River, Jingping primary and secondary stations and Guandi station of Yalong River, Dagangshan and Houziyan stations of Dadu River, and Hongjing station of Lancang River, etc. Before 2020, newly built large hydropower stations will include Wudongde and Baihetan stations of Jingsha River, Lianghekou and Yangfanggou stations of Yanlong River, and Shuanghankou station of Dadu River. By then, the economically feasible utilization rate for total hydropower resources will reach 70%. Preparation for the substitution of hydropower for traditional power generation is planned by means of the water resource investigation and utilization plan for the area upstream of Three Rivers (Sanjiang) in east of Tibet and Brahmaputra.

Given the development plan above, by 2010, China’s installed hydropower capacity will reach 190GW, 120 GW of which will be from large hydropower stations, 50GW from small hydropower stations, and 20GW from water pumping stations. By 2020, China’s installed hydropower capacity will reach 300GW, 225GW of large hydropower and 75GW of small hydropower.

7.3.2 Biomass Energy

Based on consideration of the demand from economic and social development and the biomass technology utilization situation, the priorities for biomass energy development in China will be biomass power generation, biogas, biomass pellets (used directly as fuel), and liquid bio-fuels.

1. Biomass power

Biomass power includes power generation using biomass from agriculture and forestry product waste, MSW, and biogas. The priorities for biomass power development are as follows:

（1）China aims to build biomass straw power generation plants in main crop production areas, or replace small coal burning power generation plants with biomass straw. It aims to build biomass power generation plants using crop stalks, bagasse, shrubbery, forestry product waste in medium and large agricultural product factories, forestry and forestry product plants, as well as in the areas of forestry and shrubbery. By 2010, the installed capacity of biomass power based on agricultural and forestry waste will reach 4GW, and by 2020, the capacity will be 24GW. Energy plantations will be grown in marginal areas including barren mountains and land to supply feedstock for agricultural and forestry based biomass power generation.

（2）MSW combustion power plants will be built in economically-developed but land resource-constrained areas. The priority sites are municipalities directly under the Central Government, provincial capital cities, coastal cities, sight-seeing cities, and cities next to main rivers and lakes. By 2010, the installed capacity of power generation based on MSW will be 500 MW, and 3GW by 2020.

（3）China will promote large-scale biogas projects with power generation systems in large-scale livestock farms, industrial organic effluent and municipal sewage plants. 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 billion m^3 biogas and total installed capacity of 1GW. 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 billion m^3 biogas and total installed capacity of 3GW.

2. Biomass Pellets

Biomass pellets can be used as fuel for cooking and heating farm households, and as fuel for decentralized heating in urban areas due to its advantages of easy storing, transporting and usage, as well as clean and high combustion efficiency. The priorities for biomass power development are as follows:

（1）By 2010, addressing the integrated priorities of meeting basic rural energy needs and also changing the mix of energy used in rural areas, 500 pilot biomass pellet fuel use areas will be established. By 2010, the annual consumption of biomass pellets fuels, including fuel supply to nearby households and commercial fuel product sold to urban households and industrial users, will reach 1 million tons,

（2） By 2020, the use of biomass pellet fuel in China nationwide will reach 50 million tons. By that time, biomass pellets will have become a widely used form of high quality fuel. The production of biomass pellets will consist of two main ways: one is in decentralized and small scale production in agricultural areas, where biomass pellets are produced from agricultural straw nearby, and mainly used as fuel by households, or sold as commercial fuel products; the other way is centralized and large scale production in suitable areas, and used as commercial fuel by industrial users and urban residents.

3. Biogas and Biomass Gasification

Making full use of biogas technologies and technologies for biomass gasification of agricultural and forestry waste is an important measure for raising the share of gas in the energy used to meet the daily life needs of rural people. It is also an important measure for resolving the environmental problems associated with rural wastes and organic industrial wastes.

In rural areas, the main emphasis will be put on household biogas digesters. In small and medium-sided towns, as well as livestock farms and in cases of industrial organic effluent, large scale biogas projects will supply gas in a more concentrated fashion. By 2010, about 40 million rural households (160 million people) will use biogas as their main fuel, and the annual consumption of biogas will be 15.2 billion m^3. By 2020, 80 million households (300 million people) will do so, and the annual consumption of biogas will be 30.8 billion m^3.

4. Liquid Bio-fuels

Liquid bio-fuel, as an important substitution for gasoline, mainly consists of bio-ethanol and biodiesel. Given current conditions of land resources and agricultural production, China aims to build scaled-up feedstock bases and large scale liquid bio-fuel production plants while selecting and breeding energy crops. China will promote technology for producing bio-ethanol from the stem of grain sorghum, sugar cane and cassava; promote technology for producing bio diesel from oil plants, like Jatropha curcas L., Pistaciachinesis Bunge, Vernicia fordii (Hemsl.) and cottonseed; and promote the establishment of a recycling system of waste edible oil from restaurants etc. By 2010, China is to build pilot projects for producing bio-ethanol from non-food grain feedstock and producing biodiesel from energy crops. By 2020, China aims to utilize 10 million tons bio-ethanol and 2 million tons biodiesel, replacing 10 million tons of petroleum-based fuel annually.

7.3.3 Wind Power

Through the large-scale development and establishment of wind farms, China aims to accelerate wind energy technology improvement and industrial development. It will also reduce wind power cost through wind turbine manufacture localization, thus promoting the market competitiveness of wind power. China plans to build large and super large wind farms mainly in the relatively developed eastern coastal areas, and in the “Sanbei Region” (“Three Norths Region”) with its rich wind energy resources. In addition, China plans to build small and medium wind farms in other areas according to the local resource and economic conditions. Main objectives and priority projects are as follows:

（1）By 2010, the total installed grid-connected wind capacity in China will be 5GW. About thirty 100MW-scale wind farms will be established, mainly in the eastern coastal areas and “Sanbei Region” with three 1 GW-scale wind farm bases in Jiangsu, Hebei, and Inner Mongolia.

（2）By 2020, the total installed grid-connected wind capacity in China will be 30GW. In order to scale-up wind energy development, wind energy resources in provinces such as Guangdong, Fujian, Shangdong, Heibei, Inner Mongolia, Liaoning, and Jilin will be exploited in adjacent swaths, thus establishing a backbone of major wind provinces, each with over 2 GW of capacity installed. Six wind farm bases including Dabancheng in Xinjiang, Yumen in Gansu, the eastern coastal area around Jiangsu and Shanghai, Huitengxile in Inner Mongolia, the Zhangbei Region of Hebei, and Baicheng in Jilin, will be developed each with a GW-level installed capacity. In addition, 1GW offshore wind capacity will be installed.

7.3.4 Solar Energy

1. Solar Power

China will promote home solar systems and small off-grid solar PV stations, which have the advantage of decentralized power generation, to provide power in off-grid rural areas. It also aims to promote Building Integrated Solar PV (BIPV) system in urban areas to facilitate meeting market demand for solar PV power generation. Finally, China plans to build solar PV and solar thermal power generation stations so as to pilot the solar energy technology utilization for the future. Main objectives and priority projects are as follows:

（1）Solar PV home systems and small off-grid solar PV stations will be built to supply electricity to rural villages and households without electricity, mainly in the areas of Tibet, Qinghai, Inner Mongolia, Xinjiang, Ningxia, Gansu, and Yunnan provinces. By 2010, China will install about 100MW of solar PV capacity to supply 1 million agricultural and husbandry households in rural areas. Then, during the 12th Five Year period, 100MW more solar PV will be installed and another 1 million households will be electrified.

（2）In large and medium size wealthy/developed and highly modernized cities, BIPV will be installed, firstly on public buildings for pilot, and then on other buildings. Meanwhile, China will promote solar PV applicants in public facilities like roads, parks and stations. By 2010, around 10,000 BIPV will be built with total capacity of 50MW, and by 2020, 200,000 BIPV with 1GW total capacity will be built.

（3） China also plans to build relatively large solar PV and solar thermal power stations. By 2010, two large solar PV power pilot stations will be built, with capacity of 20MW, and by 2020, a total of 200MW of solar PV power stations and 200MW of solar thermal power stations will be built.

Given the solar energy technology utilization in three main fields mentioned above, the total capacity of solar PV power generation by 2010 will be 300MW, 150 MW of which will be for rural electrification, 100MW of which in BIPV, and 20MW of which in large grid-connected solar PV stations, with other commercial applications equal to 30MW. By 2020, the total capacity of solar PV will be 1.8GW, 300MW of rural electricity, 1GW of BIPV, 200MW of grid-connected solar PV stations and 200MW of solar thermal power stations, and 100MW of other commercial applications.

2. Solar Thermal Applications

China aims to promote building-integrated solar thermal systems and pilot solar space heating and cooling technologies in urban areas, and to promote household solar water heater, solar building, and solar cookers in rural areas. By 2010, the total heat collecting areas of China's solar water heaters will be 150 million m^2, plus other applications of solar thermal applications, providing 30 million tce. By 2020, the collector areas will reach 300 million m^2, plus other applications of solar thermal applications, providing 60 million tce.

7.3.5 Other Renewable Energy Applications

China will actively promote the development and utilization of geothermal and ocean energies. Geothermal energy resources will be used to a reasonable extent, making sure to meet environmental protection and water resource protection requirements. Geothermal energy will be used for heating, hot water supply, and geothermal heat pumps. Geothermal power generation will be developed in areas with high-temperature geothermal resources. R&D for power generation using deeper geothermal resources will be promoted. In the regions of Zhejiang, Fujian and Guangdong provinces, tidal power generation will be promoted, as will R&D for power generation using ocean energy like waves. By 2010, the target of annual geothermal energy utilization will be 4 million tce, and 12 million tce by 2020. The total capacity of tidal power generation will be 100 MW by 2020.

7.3.6 Rural Renewable Energy Applications

In rural areas, renewable energy applications will be developed to resolve issues of daily use energy for China's vast rural population, to improve rural production and living conditions, and to protect the ecological environment. Use of renewable energy will effectively raise rural incomes and increase the speed of social and economic development in rural areas. The priorities for development are the following:

（1）Supply power to rural areas without electricity: For those areas to which it would not be economic to extend the power grid, full play should be given to the strengths of local resources. In these areas, through the application of small hydro, solar, and wind, as well as other renewable, the basic electricity demand of people without power supply will be solved. In areas with rich resources of small hydropower, top priority will be given to develop small hydropower stations (including micro hydropower stations), resulting in the supply of energy to totally around 1 million households. In those areas lacking small hydropower resources, electricity will be supplied to around another 1 million households by means of, depending on local resources, building small-scale off-grid solar PV power stations and wind-PV hybrid power stations, as well as by promoting the use of small household wind turbines, solar (PV) home system, and wind-PV home systems. By 2015, China will entirely solve the problem of power supply in areas without electricity by extending power grid and installing stand alone renewable energy power generation systems.

（2）Improve conditions of rural daily-life energy use: Rural living conditions and the quality of rural people's lives will be improved by means of utilization of various renewable energy technologies. Small hydropower will serve as a substitution for fuel. Household biogas digesters, biomass pellet fuel, solar water heaters, and other renewable energy technologies will also be used to supply clean energy to rural areas. By 2010, 30 percent of rural households will use clean renewable energy, with 40 million rural household biogas digesters, and 50 million m^2 of solar water heater collecting areas in use in rural areas. By 2020, 70 percent of rural households will use clean renewable energy, with 80 million rural household biogas digesters, and 100 million m^2 of solar water heater collecting areas in use in rural areas.

（3）Establish Pilot Green Energy Counties: Adopting the principles of flexibility, diversification, and taking action suitable to local circumstances, China will establish pilot Green Energy Counties in areas with abundant renewable energy resources, striving to make full use of all kinds of renewable energy. In a Green Energy County, more than 50 percent of household energy comes from renewable energy, and various biomass residues and wastes are treated and utilized in reasonable ways. The number of pilot green energy counties will be 50 by 2010, and 500 by 2020.