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China Renewable Energy Scale-up Program
中国可再生能源规模化发展项目

中国可再生能源产业发展报告2009（中英文版）

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THE RENEWABLE ENERGY INDUSTRIAL DEVELOPMENT REPORT 2009

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Foreword

2008 is a fruitful year for renewable energy development in China. By the end of 2008, China's hydropower installed capacity has reached 170 million kilowatts, ranking No. 1 in the world; total installed capacity of wind power doubled in three consecutive years, as the world's fastest-growing wind power market, reaching 12.15 million kilowatts; and the cumulative market share of domestic funded and joint ventures increased to 61.8%, which for the first time exceeded the foreign-funded enterprises; Solar photovoltaic cell production of 2 million kilowatts maintains an absolute advantage in the world; total solar water heater usage is over 125 million square meters, accounting for more than 60% of the world's total solar water heater use; biomass, geothermal and other renewable energy have also developed. Without considering the traditional use of biomass, China's renewable energy usage is about 250 million tons of standard coal in 2008, accounting for 9% of the total primary energy consumption.

During this year, with the "Renewable Energy Law" as the core, renewable energy policy system has been further improved. The "Eleventh Five-Year Renewable Energy Development Planning" has been issued, explicitly stating the guiding ideology, development goals, overall layout, key areas and safeguard measures of renewable energy development in the "Eleventh Five-Year" period, introducing a series of fiscal incentives and vigorously promoting the development and utilization of renewable energy. For policy implementation, co-ordination and supervision has been strengthened. The framework of the implementation and monitoring system has been established, composed of three aspects, which are supervisory of state power organs, the executive branch implementation and supervision, the social implementation and supervision, creating an enabling environment for renewable energy development.

Despite of the gratifying results, we should be aware that China is facing with an important stage of transition from a large consumer of renew-

able energy to a powerful giant of renewable energy utilization. During this stage there are still some problems in different levels in aspects of resource assessment, technology research and development, reasonable pricing, grid access, market norms for renewable energy development and so forth, thus the China government, research institutions and enterprises need to encounter together and seriously address.

At present, the global financial crisis has not been eased at root while the pressure from global climate change is intensified. Developing renewable energy can not only create a new economic growth point, but also effectively reduce the greenhouse gas emission, therefore it wins great attention and support among the international community. China should seize this opportunity and make use of all positive advantage upscale renewable energy utilization contributing to jointly cope with the climate change issuer.

Author

Content

1 Introduction of Renewable Energy Development

1.1 Overview of Renewable Energy Industrialization

1.1.1 Overall Situation of Renewable Energy Development

Since the Renewable Energy Law promulgated in 2006, the development of renewable energy in China has stepped into a new era with all kinds of renewable energy developing rapidly. By the end of 2008, the total amount of hydro power installed capacity reached 0.172 billion kW and the hydro power could generate power more than 560 billion kWh per year, which accounted for 16% of total power generation. There were additional installed capacity of wind turbines 6.5 million kW in 2008 and the accumulative total installed capacity reached 12.15 million kW. The capacity of solar photovoltaic cell production got improved and output reached 4 million kW per year, while the actual production was 2.6 million kW which made China top 1 worldwide in this field. The annual production of solar water heater is 40 million m^2 and accumulative total amount of usage is over 0.125 billion m^2, accounting for more than 60% of the world. The development of biomass energy is moving fast as well, household methane digester are more than 28 million, there're over 8 thousand places with large or medium-sized methane facilities and annual utilized quantity is 12 billion m^2.

The utilized quantity of renewable energy was about 0.248 billion tce in 2008 and accounted for 9% of the primary energy consumption that year (Details in Table 1).

1.1.2 Basic Data of Development and Utilization of All Kinds of Renewable Energy

1.1.2.1 Hydro Energy

According to the assessment result of national water resources in 2003,

Table 1 2008 China Renewable Energy Development and Utilization

	Installation	Annual production	Standard coal equivalent (10 thousand ton/year)
1. Power generation	$18,740\times10^4$ kW	$6,884.4\times10^8$ kW·h	20,536.6
Hydro power	$17,152\times10^4$ kW	$5,633\times10^8$ kW·h	19,659.2
Grid-Connected Wind Power	$1,215\times10^4$ kW	150×10^8 kW·h(60%)	523.5
Small Off-Grid Wind Power	40×10^4 kW	4×10^8 kW·h	14
Solar Power	15×10^4 kW	1.9×10^8 kW·h	6.63
Biomass power	315×10^4 kW	94.5×10^8 kW·h	329.8
Geothermal power generation	2.5×10^4 kW	1.0×10^8 kW·h	3.5
2. Gas supply(methane)		120×10^8 m^3	776.7
3. Heat supply			3,330.3
Solar Water Heater	$12,500\times10^4$ m^2		3,000
Solar Cooker	450,000		10.3
Geothermal Utilization	$4,000\times10^4$ m^2	$8,000\times10^4$ GJ	320
4. Fuel			188
Biomass Briquette			
Alcohol for Vehicle	120×10^4 ton		120
Bio-oil	50×10^4 ton		68
Total			24,831

the total available technical installed capacity of national water resources is 0.542 billion kW and the annual amount of power generation is 2.47×10^{12} kW·h; economic available installed capacity is 0.4 billion kW and the annual amount of power generation is 1.75×10^{12} kW·h. If the economic available annual amount of power generation can reuse for 100 years, the water resources account for about 40% of the national general residual available energy, only next to coal. At the end of 2008, the total national hydro power installed capacity is 0.172 billion kW, accounting for 21.7% of all; annual amount of power generation is 563.3 billion kW·h, accounting for 16.3% of all. Among which, small hydro power account is about 57 million kW and can generate 190 billion kW·h per year, taking charge of almost half of the country's area, i.e. one third of all counties and a quarter of population's

power supply task. The investigation, design, construction, installation and production of facilities in our country has already reached the international level and formed an complete industrial system. From now on, the major problem of hydro power development is disturbance of drainage area's eco-system and related social influences.

1.1.2.2 Biomass Energy

Crop straw, forestry residue, oil plants, energy crops, household garbage and other organic waste are all included in. At present, the amount of crop straw resources used as energy equals to 0.15 billion tons of standard coal, while residue of forestry resources equals to about 0.2 billion ton of standard coal. The potential planting area of oil plants and energy crops, such as jatropha curcas, rapeseed, castor-oil plant, lacquer tree, Chinese pistache, sorgo and so on can meet the raw material need of annual production of 50 million ton bio-liquid fuel theoretically. The amount of industrial organic waste water and livestock farms waste water can generate almost 80 billion m^3 methane theoretically, which equals to 57 million ton of standard coal.

By the end of 2008, the national total installed capacity of biomass power generation is 3.15 million kW, among which bagasse accounts for 1.7 million, rice husk of rice milling factory accounts for 5×10^4 kW. Power from garbage burning is 4×10^5 kW, while power from crop straw and residue of forestry is 6×10^5 kW and the rest are from several small demonstration projects of biomass gasification power generation.

By the end of 2008, there're more than 28 million household methane digesters in countryside, and over 8000 livestock farms and industrial waste water methane projects, which can generate methane about 12 billion m^3 per year.

1.1.2.3 Wind Power

China is vast in territory, has long coastlines and is rich of wind resources. The total amount of wind resources is about 3.2 billion kW, with the available wind energy resources of one billion kW. Ample wind energy resources are mainly distributed in southeast coastal area and nearby islands, Inner Mongolia, Hexi Corridor in Gansu, parts of North-East, West-East, Northern China and Qinghai-Tibetan Plateau. The national Synchronization of wind power has developed since 1980s. During the "tenth-five" plan, de-

velopment of wind power is very flourishing, the total installed capacity has been enhanced from 350 thousand kW in 2000 to 12.15 million kW in 2008, the annual average growth rate is 55% (Fig. 1). The total installed capacity ranked the 10th of the world in 2004 and this ranking changed to the 4th by the end of 2008. The development of wind power faces a series of problems like on-grid price, grid construction and so on.

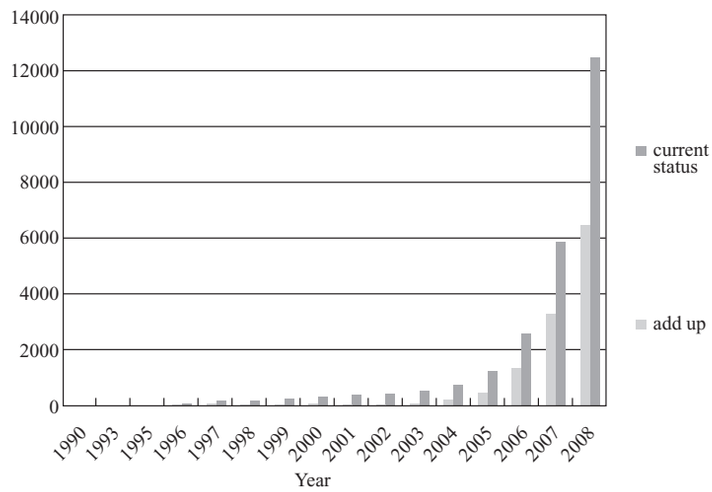


Fig. 1 The growth status of national installed capacity of wind power (unit: MW)

1.1.2.4 Solar Photovoltaic

There're more than two thirds area of China being rich in solar energy, and the annual radiation amount is over six billion J/m^2, while the received heat of surface from sun equals to 1.7×10^{12} tons of standard coal. Possessing good conditions of solar energy utilization and rich solar energy resources, especially in North-West, Tibet and Yunnan, etc. By the end of 2008, annual production of cell is 2.6 million kW and domestic installed capacity is 40 thousand kW, the accumulated total power capacity is 150 thousand kW, among which separated photovoltaic power system accounts for 55%, using for supplying power to those places that the grid cannot reach. Besides, a portion of industrial fields such as communication and the market of photovoltaic consumer products are increasing as well (Fig. 2).

1.1.2.5 Solar Thermal Utilization

The most widely utilization way of solar energy is solar water heater at

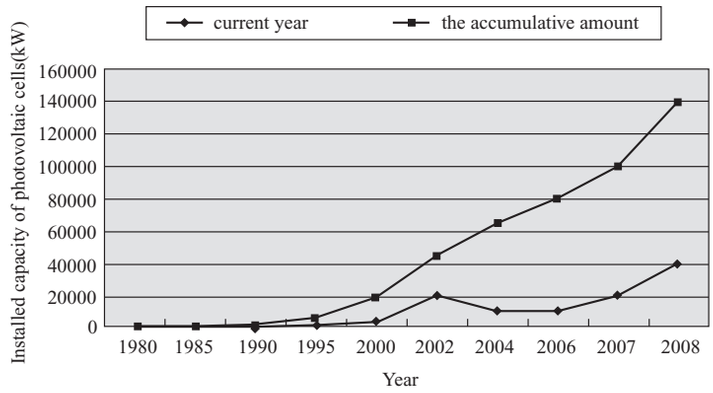


Fig. 2 The installed capacity and accumulative total installed capacity of photovoltaic cells in China

present, mainly using for supply household washing water and plays a vital role in improving living standard in small-medium sized cities. The accumulative heat collecting area of installed solar water heater is $1.25 \times 10^8 m^2$ by 2008, the annual energy generation is 40 million m^2, in which the amount of 2008 accounts for 31 million m^2. Both the amount of usage and annual generation in China accounts for over 50% of the whole world (Fig. 3). In recent years, with the improvement of technologys combination with architecture, there's a series of projects that connect solar water heater with buildings in China and the concept that solar water heater and real estate project design, construct and check in the same pace has gradually be accepted by the architectural industry. Besides solar water heater, we are developing and enlarging solar utilized fields, including heating supply, desalination of sea water and industrial heating and so on, and have already started to do prophase research and construction of demonstration system.

1.1.2.6 Geothermal Energy Utilization

Geothermal energy utilization can be divided into direct use and indirect use. The distribution of high-temperature geothermal energy national wide is difficult, since it mainly concentrates in Hengduan Mountain Range in Tibet and Yunan. The areas that have already been investigated and exploited mainly concentrate in Yangbajing in Tibet and Tengchong in Yunan. At present, the direct usage of geothermal resources is developing in a healthy way

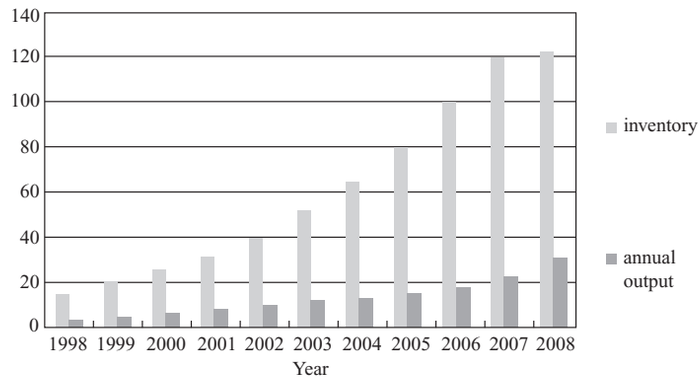


Fig. 3 Inventory and annual output of solar water heater (unit: 10^6 m^2)

to scale-up and industrialization orientation. According to the statistics, the amount of direct use of geothermal energy is 12,604.6 GW·h by 2004, the capacity of facilities is 3,687MW, respectively ranked No.1 and No.3 in the world. China exploited 0.46 billion m^3 of geothermal water in 2006, equaling to 3,239 MWt, while utilized energy is 11,426 GW·h. If the utilization of ground source geothermal pump is added, the total utilized amount is 16,187 GW·h, equaling to 58.3×10^{15}J and 2.53 million tons of standard coal. The annual carbon dioxide emission reduction is 6.03 million tons and sulfur dioxide emission reduction is 0.1518 million tons. The sustainable development of geothermal energy makes great contribution to the emission reduction work in China.

1.1.2.7 Ocean Energy Utilization

The Ocean energy mainly includes tide energy, wave energy and ocean current energy, etc. There're eight tidal power station be established already, and our country is seeking for a new way for tidal power generation, and conducting technological research and demonstration. The exploitation of wave energy technology develops fast in recent years. Since "seventh-five" plan, we have made great progress in conversion efficiency, stable output and technology of device construction of wave energy. The self-developed separated wave energy power system had transferred the unstable hydraulic power of which the average power is 8kW and the fluctuation is 8kW, into stable electric power successfully. By the end of 2008, there're one 100kW and 20kW off-shore OWC wave energy devices and more than 700 1kW (or below) devices.

1.2 Insight to Renewable Energy Policy

The RE Law, enforced on February 28, 2005, set up a series of relatively complete regulations with respect to the improvement of RE development and utilization, and created the legal and policy framework for the development of RE market. Therefore, the RE law in China is basically a general framework of legislation and policy. To further foster the effective implementation of this law, associated work should be conducted in three aspects:

Firstly, to address the research and establishment of associated administrative procedures and technical standards so as to be able to formulate a complete legal system consisting of national and local laws, regulations administrative regulations, rules, technical standards, etc. ;

Secondly, to set up the implementation mechanisms and instruments of the Law, as well as a complete administrative management procedures, monitoring and governance systems by encouraging public participation and social supervision; thirdly, to further cultivate the RE market system and industry development in order to create favorable market environment and industry foundations.

In order to promote renewable energy development, several important regulations were developed such as the Renewable Energy Law, Feed-in Law, Categorized Pricing, Cost Sharing, Special Fund Mechanisms, taxation and credit system, etc. Since the law promulgated in 2005, related departments including NDRC, Ministry of Finance, State Power Supervision Committee (SPSC), Ministry of Construction and SAC, issued more than 20 supporting policy one after another. Thereby, the framework of renewable energy policy in China basically formed.

First, Mid-long Term Development Plan for Renewable Energy and The Renewable Energy Development Planning during 11th Five Year Planning Period had been issued, making clear the immediate-mid-term goals of national renewable energy development and conducting government at all levels as well as all sections of society to develop renewable energy.

Second, with the implementation of The Management Regulations for Re-

newable Energy Power Generation, The Trial Management Measures for Renewable Power Pricing, The Catalogue of Guide to Renewable Energy Industry Development and The Regulations of Power Enterprises Buyout for Renewable Energy Electricity established a enforce system to request power enterprises accepting the renewable energy electricity. On the other hand, established the categorized pricing system of renewable energy power generation according to different technologies and industrialization processes, which eliminate the obstacle of admission so that lots of funds from society are attracted.

Third, with the publication of by-laws like The Trial Management Measure for Allocation of Renewable Energy Tariff Surplus Revenue, China establish the cost sharing mechanism for all society, make clear that the limit of additional price and way of collection and usage, and enlarge the renewable energy market.

Fourth, with a series of supporting policy for wind power generation, biomass energy utilization and solar energy power generation combined with buildings of implementation of renewable energy special development funds, such as The Trial Management Measures for the Special Development Fund and The Trial Management Measures for the Special Fund of Wind Power Equipment Localization, the framework of financial input that support technological research on renewable energy, industrial development, application for market and other aspects are formed;

Fifth, with the publication of a series of technical standards that concern with production, application, construction and installation of renewable energy such as The Technical Regulations for Solar Water Heater Building for Civil Use, The Technical Regulation on Wind Farms to Connect Power Grid and so on, a clear orientation for industrial development and standardization is made.

Sixth, the taxation system that promotes renewable energy development has already set up initially. Except for several tax policy such as the value-added-tax of tidal power generation refund upon collection that enforced since 2001, the value-added-tax halving of wind power generation and preferential customs for key components import of wind power generation

that specially set up in 2008, in recent promulgated tax policy in 2008, according to enterprises income tax preferential catalog of integrated utilization of key resources and public infrastructure projects, division for high-tech fields that are greatly supported by China government, giving enterprises income tax preferential policy in different levels for the development of renewable energy projects that concern with integrated utilization of biomass energy, wind power generation, solar power generation, as well as related enterprises that in charge of equipment, production and manufacture. Furthermore, in transition process of national value-added-tax, greatly lightening the burden of enterprises' tax during project development owing to no need for fuel cost of renewable energy projects exploitation and the value-added-tax that emerged in disposable facilities purchase can offset the enterprises' value-added-tax. In a word, various new tax policy made by the country and the taxation system specialized for renewable energy indicates the great support for renewable energy development from the government.

Besides above measures, relevant departments also carry out resource investigation, concession bidding, quota system for enterprises and promote the renewable energy industry forward a sound and fast development according to the laws. Under the encouragement and guidance of these policy, the renewable energy market in China are enlarged constantly, the technical levels are improved constantly. What's more, there's an obvious increase of income funds and the renewable energy industry shows good tendency of development. Meanwhile, the effort we spent on renewable energy aspect receives international recognition and brings positive influence on our participation of international affairs.

Column 1: Renewable Energy Policy, Regulations and Standards

1. The Renewable Energy Law passed on February 28, 2005 by the 14th Session of NPC Standing Committee

2. The Catalogue for the Guidance of Renewable Energy Industry Development NDRC Energy No. (2005) 2517

3. The Trial Management Measures for Renewable Power Pricing and Cost Share NDRC Price No. (2006) 7

4. The Management Regulations for Renewable Energy Power Generation NDRC Energy No. (2006) 13

5. The Trial Management Measure for the Special Fund of Renewable Energy Development MOF Construction No. (2006) 237

6. Implementation Notes of Enhancement of Renewable Energy Industry Development NDRC Energy No. (2006) 2535

7. The Trial Management Measure for Allocation of Renewable Energy Tariff Surplus Revenue NDRC Price No. (2007) 44

8. The Notice for Enhancement of Bio-ethanol Project Construction and Management NDRC Industry No. (2006) 2842

9. The Management Measures for Product Oil Market MOC (2006) 23

10. The Standard for Fuel Ethanol GB 18350—2001

11. The Standard for Vehicle Ethanol GB 18351—2004

12. The Trial Management Measure for the Special Fund of Renewable Energy Buildings MOF Construction No. (2006) 460

13. The Evaluation Measure for Renewable Energy Building Pilot Projects MOF Construction No. (2006) 459

14. The Management Regulations of Wind Power Project Construction by NDRC NDRC Energy (2005) 1204

15. The Trial Management Measures for Wind Power Project Land Occupation and Environmental Protection NDRC No. (2005) 1511

16. The Technical Regulations for Solar Water Heater Building for Civil Use GB 50364—2005

17. The Technology Regulations of Wind Farm Integration into Power Grid by the State Grid Corporation (in trial) State Grid Development No. (2006) 779

18. The Design Regulations for Wind Farm Integration System by the State Grid Corporation State Grid Development No. (2006) 779

19. The Mixed Bio-diesel for Diesel Engines GB/T 20828—2007

20. The Mid-Long Term Development Planning for Renewable Energy Development by NDRC in September 2007

21. The Renewable Energy Development Planning during 11th Five Year Planning Period by NDRC in March 2008

22. The Trial Management Measures for Tariff Return of Chinese Brand Equipment Purchase by Foreign Investment Projects Tariff No. (2006) 111

23. Import Tariff Adjustment for Large Wind Turbines, Key Components and Raw Materials by Ministry of Finance MOF Tariff (2008) 36

24. The Trial Management Measures for the Special Fund of Wind Power Equipment Localization MOF Construction (2008) 476

From the overview of associated regulations and rules, the implementation framework of the Renewable Energy Law has already been set up. Whereas aspects such as price setting of renewable energy products, allowance mechanism, approving projects system and so on need further improvement.

Besides, the situation of the RE Law implementation in China reflects that three-dimensional implementation and supervision systems are formed by the supervision of the national authority, its implementation and supervision by the administrative departments, and its implementation and supervision by the society.

The national authority could follow up the implementation status of the law and push the related administrative departments for its effective implementation through legal examination, listening to reports of governmental departments, special research and other methods that are conducted by the Standing Committee of NPC at all levels. Currently, the Environment and Resources Committee of the NPC and the corresponding committees in charge of environment and resources as well as finance and economy at local levels take the responsibility of examination and supervision work.

With regards to the administrative implementation and supervision, the

national and local Development and Reform Commissions dominate the implementation of the RE Law and at the same time the departments in charge of finance, science and technology, technical supervision, etc. exert specific legal functions and their administrative obligations according to the law. Within the State Council, it involves over ten ministries and departments (see Table 2).

Table 2 The Institutional Arrangements of State Council for Implementation and Supervision of Renewable Energy Law

1. Overall Administration
National Energy Administration
National Development and Reform Commission
Ministry of Finance
Ministry of Science and Technology
2. Administrations by Sectors
Ministry of Agriculture
Ministry of Housing and Urban-Rural Development
Ministry of Environmental Protection
General Administration of Quality Supervision, Inspection and Quarantine
State Forestry Administration
China Meteorological Administration
3. Independent Supervision
State Electricity Regulatory Commission

The implementation and supervision experience show that civil organizations have become an important force in supervision of the law's implementation in recent years. Some of the environmental protection and energy organizations including industry association and environment civil organizations are greatly concerned about RE development and utilization. On one hand, they give active support for the utilization of wind power, solar power and biomass, and on the other hand, they are worried about the biological damages brought with the rapid development of hydro power. These organizations have greatly push the participation of the whole society in the establishment of these laws and regulations. Organizations that pay attention to RE can be divided into three categories: those on behalf of the RE industry as-

sociations and groups including All-China Federation of Industry & Commerce, Chinese Renewable Energy Industries Association, etc; the RE academy groups and organizations including the Academy of Renewable Energy, Chinese Society for Environmental Sciences, etc; and the civil environmental protection organizations that conduct special activities in RE area. In addition, the international environmental protection organizations have also exerted important influence to the RE development in China (see Table 3).

Table 3 Societies and Associations Concerned in China

All-China Federation of Industry & Commerce
Chinese Renewable Energy Society
Solar Thermal Utilization Association
Solar Photovoltaic Association
Solar Photochemistry Association
Solar Building Association
Wind Energy Association(China Wind Energy Association)
Biomass Energy Association
China Rural Energy Industry Association
Small Power Source Association
Bio-gas Association
Biomass Energy Conversion Technology Association
China Energy Enterprise Management Association
China Agriculture Environmental Protection Association
China Energy Research Society
Chinese Renewable Energy Industry Association
China Society for Hydro Power Engineering
China Energy Conservation Association
China Resource Recycling Association
Chinese Hydraulic Engineering Association
Chinese Society for Environmental Sciences
China Association of Environmental Protection Industry
Environment Education Center of Beijing Earth Village
Friends of Nature

This shows that the public participation and social supervision have played a positive role in RE development in China. Some associations have even been actively involved in the research and drafting of the RE Law, associated rules and regulations, technical norms and standards, as well as in the RE planning. They

have also participated in the information dissemination and education activities, as well as implementation of some projects that make considerable contributions to the establishment and implementation of related laws, policies and plannings.

On the whole, it is lack of general coordination mechanisms. Different departments in the NDRC are in charge of different functions. These departments include the Energy Bureau, the Economic Operation Bureau, the Price Department, the Industry Department, the High-tech Industry Department. They take charge of RE planning, project approval, energy allocation, prices and industry development respectively. MOF is in charge of the related budget and the arrangement of the RE Special Fund; The Ministry of Science and Technology (MOST) is in charge of project demonstration of important technologies; The State Power Supervision Committee is in charge of market supervision of RE power. It would not be possible for just one single department or ministry to overall manage the administrative functions, take responsibilities of related resources investigation and planning, nor can any department take all responsibilities of scientific and technological research, technical demonstration and promotion or be responsible for supporting industry development, project approval and pricing.

2 Wind Energy

2.1 China's Wind Energy Resource

China is rich in wind energy resources, but her wind resource assessment and wind farm layout is far to meet the wind energy industrial development. Wind resource assessment can be categorized into macro, middle and micro level and such levels are functioning to different purposes of strategy and planning, wind farm layout, project design, etc. CMA conducted the first wind resource assessment in late 1970's at the macro level, followed by several assessments at national level later. While to meet the increasing data demand, it is necessary for making a more detailed wind assessment. The main results are summarized as follows:

In late 1980's, CMA utilized the data (data compiled before 1980's) collected by more than 900 field stations all over China and conducted the second wind round resource assessment. It was concluded that the theoretical wind resource storage at 10 m height was 32.26×10^8 kW and the technical availability was 2.53×10^8 kW. The concept "for technical availability area" was defined as the wind resource area with wind power density of more than 150 W/m^2 at 10m height.

During 2004 to 2005, CMA conducted the third round wind resource assessment, collecting and compiling the data for the last 30 years (1971 to 2000) from 2384 weather stations. The result modified the data analysis for the last two wind resource assessment. It was concluded that the theoretical wind resource storage at 10 m hight was 43.5×10^8 kW and the technical availability was 2.97×10^8 kW. And the technical availability area was 0.2 million km^2.

During 2003 to 2005, UNEP organized the wind resource assessment. The simulation model was utilized to analyze the wind resource for 3 million

km^2 in east of China and coastal area. The 10 met masts at 70m height is funded by UNEP, the data are collected from 170 weather stations and more than 60 existed met masts verified the simulation. The result provided the technical availability of wind resources at 50m height. It was concluded that the onshore (excluding provinces/autonomous regions of Xinjiang, Qinghai, Tibet and Taiwan) theoretical wind resource storage at 50m height was 0.284 million km^2 and 14.2×10^8 kW. The technical availability was 14.2×10^8kW. The concept "for technical availability area" was defined as the wind resource area with wind power density of more than $400W/m^2$ at 50m height. NREL was entrusted with the simulation, which set 15 wind resource area with about 2.676 million km^2, which didn't cover the east area, but cover all the rich and typical wind resource area east of China. An assumption was set that 5MW installation per km^2 at 50m height. It was concluded that the wind resource storage was the 32.5×10^8 kW, 0.65 million km^2 area with more than $300W/m^2$ wind power density and the 14.2×10^8 kW, 0.284 million km^2 area, with more than $400W/m^2$ wind power density and the technical availability was 2.97×10^8 kW.

CMA conducted the wind resource assessment by simulation during 2006 to 2007. It further detailed the wind resource layout with high resolution and more accurate technically availability. Such work provided better reference to wind energy planning and wind farm development. It was concluded that the theoretical wind resource storage at 50m height was 26.8×10^8 kW, 0.54 million km^2. The concept of technical availability was defined as wind resource availability at 50m height with more than 400 W/m^2 wind power density.

Although there are several wind resource assessments to conclude different amounts, the distribution of rich wind resource is similar. The factors which differentiate the assessment result include methodologies, data sources, height levels, etc. The second and third wind round of assessments adopted the data at 10m height, while the last two rounds utilized simulation at 50m height. Simplifying the estimation by wind shear at 10m height, the technical availability at 50m height and 70m height shall be 6×10^8 kW and

7×10^8 kW respectively.

In conclusion, there are 0.2 million km^2 wind resources with more than 150 W/m^2 wind power density at 10m height onshore, 4 billion kW in equivalent, among which it is 0.6 billion to 1 billion kW technical availability.

Such conclusion is established at macro level, and can only provide the general reference to the overall layout of wind resources by analysis of technical availability. The wind farm location shall depend on the middle and micro level wind resources, considering more factors, including data of terrain, ground cover, power grid, etc.

The offshore wind resource assessments were conducted by CMA, NCC, CAS, UNEP, respectively. The assessment methodologies they adopted cover statistics, simulation based on atmospheric circulation combined with remote-sensing satellite. The most recent data collected by NCC told that the technical availability of offshore wind resources (with wind power density $\geqslant$400W/m^2) was 7.5×10^8 kW. The data collection and analysis adopted simulation methodologies by simulating the offshore wind resources 50km away from coast. It is the middle level wind resource assessment. And also the analysis deducted the wind resources in the area with more than three times of typhoon annually according to statistics. Although many of the research were conducted, the results cannot be finalized for the offshore wind resources in China.

All the research implies the rich offshore resources, but it is the actual explorable area decides the technical availability. The larger the wind turbines become, the larger the distance shall be between wind turbines to avoid interaction and impact of the tail waves and vice versa. Therefore, the number of wind turbines is definite for some fixed area. According to the existed technical condition, one square meter can hold 3 to 5 MW wind turbines. Based on the *Research Report of National Coastal Zone and Shoal Resources*, it can be estimated there is 157,000 km^2 sea area at the 0～20m fathom line. In 2002, the National Marine Functional Zone Planning was issued a detailed description of functional zones for shipping, fishery, tourism and engineer, etc. and planned 60 zones for ocean energy utilization, Simplifying the technical availability and deducting

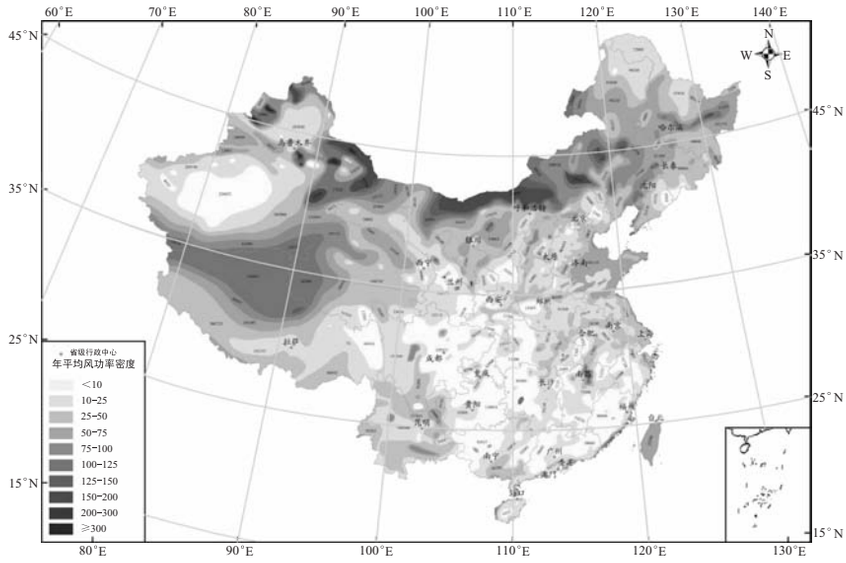


Fig. 4 the 2nd round wind resource assessment map

(annual average wind power density: 150W/m^2) Source: CMA

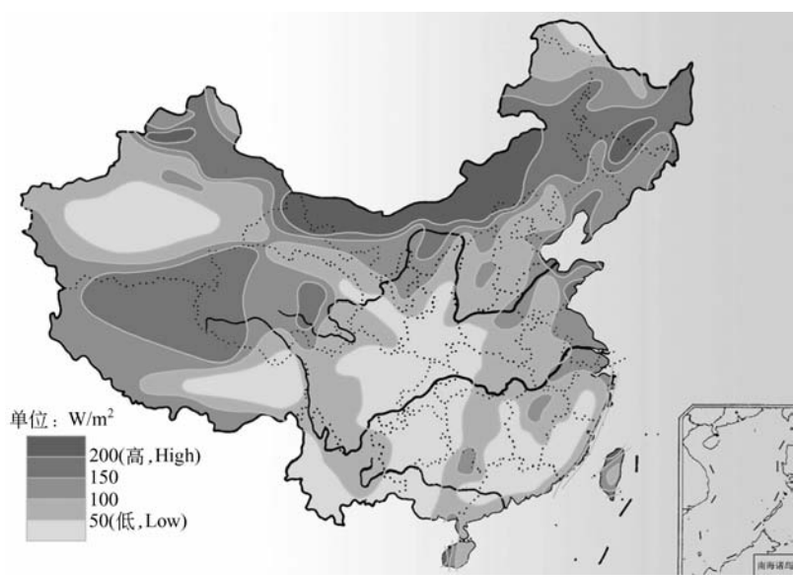


Fig. 5 the 3rd round wind resource assessment map.

Source: CMA

the functional zones, there shall be 10%～20% ocean area to be utilized and equivalent to 1×10^8 kW to 2×10^8 kW wind turbine installations. But it shall be further detailed by the national planning.

It is concluded that there are 3 rich wind resources area in China, covering the North China Zone, i. e. most area in northwest of China, north of North China, most area in northeast of China, the coastal wind zone and the Tibetan Plateau. See the two maps showing the two national wind resource assessments.

2. 2 Off-grid Wind Power

2. 2. 1 Overview

By the end of 2008, according to incomplete statistics, there are 74 units engaged in off-grid wind turbine R& D and production in China. Among them, there are 36 major manufacturers. Currently, there are 19 types of off-grid wind turbines produced in China. The annual production capacity is 80,000 units. The capacity of wind turbine varies from 100W to 100kW. In 2008, for the off-grid wind turbine smaller than 100kW, there were 78,411 sets produced 79,757 kW in total capacity with 529. 93 million Yuan turnover and 100. 23 million Yuan profit and tax.

From 1983 to the end of 2008, there are 508,712 sets off-grid wind turbines produced by various Chinese manufacturers. China ranked No. 1 in terms of annual production, total production, production capacity and exports quantity in the world (table 4 shows the production in each year).

Table 4 Summary of Off-grid Wind Turbine Production in 1983-2008 (unit: sets)

Year	Before 1983	1984	1985	1986	1987	1988	1989	1990	1991	1992
Yield	3,632	13,470	12,989	19,151	20,847	25,575	16,649	7,458	4,988	5,537
Year	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Yield	6,100	6,481	8,190	7,500	6,123	13,884	7,096	12,170	20,879	29,758
Year	2003	2004	2005	2006	2007	2008				Total
Yield	19,920	24,756	33,253	50,052	54,843	78,411				508,712

In the years of 2002 to 2008, the annual production, turnover, average capacity, profit and exports quantity of off-grid wind turbine have been developed rapidly (see Table 5).

Table 5 The Production, Capacity, Turnover, Profits and Taxes, Export of Off-grid Wind Turbine in 2002-2008

Year	2002	2003	2004	2005	2006	2007	2008	Total
Production(sets)	29,658	19,920	24,756	33,253	50,052	54,843	78,411	290,893
capacity(kW)	8,873.2	6,083.7	11,300.2	12,020	51,740.8	35,014.6	72,825	197,858
Turnover (ten thousand Yuan)	7,059.6	4,740.5	6,653.7	8,472	17,090.8	31,794.4	518,908	1,277,018
Profit and Taxes (ten thousand Yuan)	984.5	660.6	775.9	992.9	1,416.0	3,749.0	9,949	18,527
Export number(sets)	1,484	2,484	4,189	5,884	16,165	19,520	39,387	89,113

According to the statistics of 20 major manufacturers, there are 38,957 sets of off-grid wind turbine (smaller than 100 kW) exported in 2008, a 50% increase over 2007, earned 44.67 million U.S. dollars, increased 17.2% compared with 2007. Totally there were 91,715 sets exported in recent 10 years to more than 40 countries and regions, including:

Asia: South Korea, India, North Korea, Mongolia, Thailand, the Philippines, Indonesia, Jordan, Vietnam, Kazakhstan, Japan, Turkey, Israel, Lebanon, Chinese Hong Kong, Malaysia and Syria;

Europe: France, Britain, Russia, Netherlands, Ukraine, Ireland, Denmark, Spain, Austria, Belgium, Sweden, Germany, Hungary and Bulgaria;

North and Central America: United States, Canada and Cuba;

South America, Chile, Ecuador, Mexico, Dominican Republic and Brazil;

Oceania: Australia and New Zealand;

Africa: Nigeria, Kenya and Guinea.

2.2.2 Trends

In recent years, more attention were paid to the development of small wind turbine, the major trends are in the following categories:

(1) The scope of application is expanding. Increased demands come from lakes and offshore aquaculture, highway monitoring, marine traffic management, beacon lights, weather stations, TV signal relay, microwave communications station (China Unicom, China Netcom, and China Mobile) and other units. In addition, off-grid wind turbines also are used for street lamps, lawn light and in parks and villas. Domestic and international distributed generation power system has further promoted the popularization and application of the kilowatt-class off-grid wind turbine development.

(2) Average capacity increases year by year. In 2008 the mainstream unit capacity of off-grid wind turbine is still 200W, 300W, 500W, but the wind turbines of more than 1kW increased rapidly, the total production reached 19,139 units, with a total capacity of 65,435kW, accounting for 89.8% of the total capacity this year. The average capacity of kW-level wind turbine is 3.4kW. It not only meets the power consumption of daily life, but also of part of the production. Mobile communication stations, distributed generation power supply systems, border posts and foreign users also need larger power systems.

(3) The substantial increase in export. In 2008, 19 companies exported 39,387 units of a variety of off-grid wind turbine, increased by 50% compared with 2007, earned 44.67 million U.S. dollars, increased by 17% compared with 2007.

(4) "PV-wind hybrid power generation" is the direction of development.

2.2.3 Suggestions to Off-grid Wind Power Development

(1) off-grid wind power industry also needs its plans, goals, and specific measures to foster and promote the healthy development of the industry.

(2) Subsidies is needed for off-grid wind turbine users.

(3) Production enterprises should strengthen self-discipline, constantly improve the product quality and reliability, as well as strengthen the after-sales service.

(4) Continuely to strengthen international cooperation to further develop the international market. In recent years, international response to the demand for small-scale wind turbine increases every year, mainly exported to Europe and America for distributed power supply systems.

2.3 Grid Connected Wind Power

2.3.1 Wind Farm Construction and the Preparation of New Planning

2.3.1.1 Wind Farm Construction

In 2008, China installed more than 5,130 wind turbine units, with a installed capacity of 6,246 MW, compared with 3,304 MW installed in 2007, the new installed capacity growth rate is 89%.

In 2008, China's cumulative installed wind turbine is more than 11,600 units, with an installed capacity of 12.153 GW. They are distributed in 24 provinces (cities and Special Administrative Regions), of which Chongqing, Jiangxi and Yunnan were added in 2008. The cumulative installed capacity of wind power by province is showed in Table 6. Compared with the 5,906 MW cumulative installed capacity in 2007, the growth rate of cumulative installed capacity in 2008 is 106%.

The estimated feed-in wind power in 2008 is about 12 billion kW·h.

Table 6 The Cumulative Installed Capacity of Wind Power by Province in 2008 (unit: kW)

No.	Province(Municipalities and autonomous regions, etc.)	2007	2008	
		Cumulative	Added	Cumulative
1	Inner Mongolia	1,563,190	2,172,250	3,735,440
2	Liaoning	515,310	734,450	1,249,760
3	Hebei	491,450	619,250	1,110,700
4	Jilin	612,260	457,200	1,069,460
5	Heilongjiang	408,250	428,050	836,300
6	Jiangsu	293,750	354,500	648,250

Continued

No.	Province(Municipalities and autonomous regions,etc.)	2007	2008	
		Cumulative	Added	Cumulative
7	Gansu	338,300	298,650	636,950
8	Xinjiang	299,310	277,500	576,810
9	Shandong	350,200	222,100	572,300
10	Ningxia	355200	38,000	393,200
11	Guangdong	287,390	79,500	366,890
12	Fujian	237,750	46,000	283,750
13	Zhejiang	47,350	147,280	194,630
14	Shanxi	5,000	122,500	127,500
15	Yunnan	0	78,750	78,750
16	Beijing	49,500	15,000	64,500
17	Hainan	8,700	49,500	58,200
18	Henan	3,000	47,250	50,250
19	Jiangxi	0	42,000	42,000
20	Shanghai	24,400	15,000	39,400
21	Hubei	13,600	0	13,600
22	Chongqing	0	1,700	1,700
23	Hunan	1,650	0	1,650
24	Hong Kong	800	0	800
	Nationwide(except Taiwan)	5,906,360	6,246,430	12,152,790

Major domestic investors and developers of wind farms are the central or local state-owned power generation enterprises and energy-invested enterprises. Private and foreign enterprises are less, some of which share projects with state-owned companies. Part share of new installed capacity in 2008 is shown in Table 7. State-owned power generation enterprises and energy group share 76% of new installed capacity in 2008.

2.3.1.2 Wind Power Development Plan

In 2008, the newly established National Energy Administration (NEA) regarded the developing wind power as one of the important tasks to improve power supply structure and meet the goals of 2020. NEA carried out several

Table 7 The Part Share of New Installed Capacity in 2008 (not the interests of capacity)

		Capacity(kW)	Share(%)
Electricity		3,806,700	61%
	Longyuan	1,374,500	22.0%
	Datang	1,072,700	17.2%
	Huaneng	932,750	14.9%
	China Power Investment Corporation	308,250	4.9%
	Huadian	118,500	1.9%
Energy companies		959,750	15%
	China Guangdong Nuclear Power	498,350	8.0%
	Guohua	350,400	5.6%
Others			
	Hebei Construction Investment	184,900	3.0%

Note: According to the manufacturer's installed capacity statistics.

10 GW level wind power base planning in wind resource-rich regions, respectively, Gansu, Xinjiang, Hebei, Inner Mongolia, Jilin and Jiangsu.

(1) Gansu Jiuquan is a wind resource-rich region with flat terrain and suitable for scale developing. Jiuquan is planning to construct nine wind farms and has entered the implementation phase. By 2015, the installed capacity will be 12.7 GW. In August 2008, the tendering exercise of 3.8 GW of wind power equipment was completed. Combined with the projects in construction, the total capacity is over 5 GW. Northwest Power Grid Company's 750 kV EHV transmission lines are being extended to Jiuquan wind power base. According to the 2,200 equivalent full load hours, the estimate feed-in wind power is about 28 billion kWh in 2015.

(2) Xinjiang Hami region is rich in wind resources with flat terrain. Hami is planning three wind farms in the southeast of Hami, Santang Lake and Naomao Lake. The total installed capacity will be 2 GW in 2010 and 10.8 GW in 2020. A 750kV power substation will be built for the wind farms. At present, the urgent need for Hami is to do feed-in and transmission system planning, wind power consumption and storage research for the

10 GW wind power farm. According to the 2,200 equivalent full load hours, the estimate feed-in wind power is about 26 billion kWh in 2020.

(3) Wind resource-rich areas in Hebei province are mainly in Zhangjiakou, Chengde regions and the east coast, including the intertidal zone and offshore. The planed total installed capacity will be 3.4 GW in 2010,7.6 GW in 2015 and 12 GW in 2020. Wind farms within the region of Beijing-Tianjin-Tangshan power grid will connect to a 500kV power grid. Wind farms in coastal area will connect to the local 220kV or 110kV power grid. According to the 2,200 equivalent full load hours, the estimate feed-in wind power is about 26.4 billion kWh in 2020.

(4) Wind energy resource-rich areas in Jilin Province are located in its western regions, mainly in the Songyuan and Baicheng City. The planed total installed capacity will be 4.37 GW in 2010, 10.9 GW in 2015 and 23 GW in 2020. 10 booster stations of 500kV will be built to transfer electricity from wind farms to Jilin Province and the Northeast Power Grid. According to the 2200 equivalent full load hours, the estimate feed-in wind power is about 50.6 billion kWh in 2020.

(5) Inner Mongolia Autonomous Region covers an extensive area, most of which is rich in wind resources. In the 10 GW of wind power base plan, in accordance with power grid coverage, the area is divided into two parts, West Inner Mongolia and eastern Inner Mongolia. The western Inner Mongolia is covered by West Inner Mongolia power grid. There are seven planned wind farm areas, namely, Xilin Gol, Ulanqab, Hohhot, Baotou, Ordos, Bayan nur and Alashan. The eastern Inner Mongolia is covered by northeast power grid. There are four planed wind power areas, namely, Chifeng, Tongliao, Hulunbeier, and Xingan. Inner Mongolia all together planed installed capacity will be 8.04 GW in 2010,35.3 GW in 2015 and 57.8 GW in 2020. In addition to the self-consumption by Inner Mongolia, 250 MW wind power will be feed into the Northwest power grid and 1.86 GW will be feed into the Northeast power grid in 2010. In 2015,1.04 GW will feed into the North China Power Grid, 300 MW into the Northwest power grid and 1.2 GW into the Northeast power grid. In 2020,2.3 GW will feed

into the North China Power Grid, 350 MW into the Northwest power grid and 18.6 GW into the Northeast power grid. At that time, 37% of wind power will be sending outside of the Inner Mongolia. According to the 2,250 equivalent full load hours, the estimate feed-in wind power is about 130 billion kWh in 2020.

(6) Wind resource-rich areas in Jiangsu Province are mainly in the east coast, including the land, the intertidal zone and offshore. The plan is under preparation. Its envistaged total installed capacity will be 10 GW in 2020, of which 7 GW in intertidal zone and offshore. According to the 2000 equivalent full load hours, the estimate feed-in wind power is about 20 billion kWh in 2020.

If all the 10 GW wind farm plans in six provinces realized, then the national total installed capacity will be 126.3 GW, the feed-in wind power will be 281 billion kWh by 2020.

The implementation of idea of build several 10 GW-level wind power bases realized the principles of "build big wind bases, feed in main power grid". In north China, wind energy resources and land resources are very rich, but the load is small and power grid is weak. So the European model of "decentralized wind power feed in and local consumption" is not applicable. The only applicable model is "large-scale, high concentration, high voltage and long-distance transmission". This model is a great challenge to the grid companies. So when planning 10 GW-level wind power base, we should give overall consideration to wind energy resources, power generation, transmission and load in all aspects. State Grid Corporation has started Lanzhou -Jiuquan -Guazhou 750 kV High Voltage Transmission Project in March 2008. The clean wind power from 10 GW wind power base will be transmitted through the transmission channel to the electric load centers in east China.

The plan of 10 GW level wind power bases will ensure that by 2020 there will be more than 100 GW of wind power installed and more than 200 billion kWh of electricity produced and consumed. This will realize the target of national medium and long-term renewable energy development plan,

namely non-hydropower renewable energy consumption will be 3% of total electricity consumption.

The limited land resource in coastal areas is the bottleneck of large-scale wind farm development. In order to make full use of land resources, it's needed to explore new model of wind farm development. The decentralize wind power model in Denmark and Germany might be used, where local individuals or their combination built small scale wind farm and feed in the distributed grid. However, several conditions need to be achieved as follows:

① The rural power supply is stable with no power interruption;

② The technical requirements of grid connection for individual wind turbines are developed;

③ Equipment manufacturers are able to assume wind turbines operation and maintenance services;

④ The Government issued feed in tariff of wind power so that the investors can make reasonable profit.

2.3.2 The Status Quo of Grid-connected Wind Power Equipment Industry Development

Domestic enterprises have basically mastered the manufacturing technology of megawatt-class wind turbine. The main components of wind power equipments can be made in China. The wind turbine production doubled in 2008 and market competition formed. The experimental prototype of 2MW to 3MW wind turbine produced one after another, some of which produced in small scale. These turbines need test running in field and improving when problem found.

2.3.2.1 Wind Turbine Manufacturers

(1) Market share in 2008

The market share of domestic and joint venture producers are 75.6% of total installed capacity in 2008. Among them, Sinovel Wind Power has the largest share, accounting for 22.5% of the total installed capacity in 2008 and 29.7% of domestic and joint venture producers.

Foreign producers share covers 24.4% of the total installed capacity in 2008. Vestas from Denmark has the largest share, accounting for 9.6% of the total installed capacity in 2008 and 39.3% of that of foreign producers.

(2) Cumulative market share

The domestic and joint venture producers accounted for 61.8% of cumulative installed capacity. It's the first year that cumulative installed capacity of domestic and joint ventures producer exceeded that of foreign producers. Gold Wind has the largest share, accounting for 21.6% of cumulative installed capacity and 35% of the domestic and joint venture producers.

Foreign producers accounted for 38.2% of cumulative installed capacity. Spain's Gamesa has the largest share, accounting for 12.8% of cumulative installed capacity and 33.4% of that of foreign producers.

In 2008 cumulative market share of wind turbine manufacturers shown in Table 8.

Table 8 Cumulative Market Share of Wind Turbine Manufacturers in 2008

2008				Cumulative			
Brand (Manufacturer)	Capacity (kW)	Proportion of domestic and joint-venture or foreign	Proportion of total installed capacity	Brand (Manufacturer)	Capacity (kW)	Proportion of domestic and joint-venture or foreign	Proportion of total installed capacity
Total	6,246,430		100%	Total	12,152,790		100%
Total domestic capital and joint ventures	4,720,430	100%	75.6%	Total domestic capital and joint ventures	7,506,220	100%	61.8%
Sinovel	1,402,500	29.7%	22.5%	Gold Wind	2,629,050	35.0%	21.6%
Total Foreign	1,526,000	100%	24.4%	Total Foreign	4,646,570	100%	38.2%
Vestas	599,700	39.3%	9.6%	Gamesa	1,552,500	33.4%	12.8%

(3) The trend of domestic entire wind turbine manufacturer's development

The domestic wind turbine manufacturers can be divided into four groups according to their development history. The first group is composed of the manufactures that already have mass production capabilities in 2007,

including Gold Wind, Sinovel, Dongfang, Windey and Shanghai Electric. These manufactures account for 85% of domestic and joint-venture installed capacity and 64% of the total installed capacity in 2008. But their technologies are mainly through the introduction of licensing, without independent intellectual property rights.

The second group is manufactures that have made experimental prototype in 2007 and has enter the top ten manufacturers of installed capacity of domestic and joint ventures in 2008, including Mingyang, Xiangdian, Xinyu and Beizhong. These manufactures accounted for 9% of the domestic and joint-venture installed capacity and 7% of the total installed capacity in 2008. Among them, Xiangdian and Beizhong introduced product technology through licensing, Xinyu used domestic R&D results and Mingyang is developing independent technology with foreign designer.

The third group is the manufactures that have installed their own wind turbine in field in 2008 but not within the top ten manufacturers of installed capacity of domestic and joint ventures, include Huachuang, Hanwei, Lianhe, Dongli, Huide, Huayi, Yuanjing, Haizhuang, Yinxing, Tianwei, Lanzhou Electric, Nanche Shidai, Sanyi Dianqi and so on.

The forth group are about 50 companies who are preparing to engage in wind turbine manufacturing.

(4) The brief introduction of some major domestic wind turbine manufacturers (by the end of 2008)

Goldwind Science and Technology Co., Ltd. (listed company, industry background: wind farm developer).

Founded in 1998, the company engaged in large-scale wind turbine research, development and manufacturing. The company introduced 600kW and 750kW wind turbine technology from abroad and made mass production. Of which 600kW model was no more produced in 2006; after more than 3,000 sets of production, the output of 750kW model will be reduced. The 1.5MW model was put into mass production in 2007. One of this model was installed in the oil field of China National Offshore Oil Corporation (CNOOC), becoming China's first offshore wind power unit. Gold Wind was lis-

ted in the Shenzhen Stock Exchange on December 26, 2007. In 2008 Gold Wind acquired 70% stock of German VENSYS Energy Company Limited through its wholly-owned subsidiary in Germany, German Gold Wind limited. Gold Wind has become the first Chinese wind turbine manufacturer which has independent R&D capability and complete independent intellectual property rights. This opens the door to the international market for its products. The company exports 6 sets of 750kW units to Cuba in 2008. Now the company is developing prototypes of 2.5MW and 3MW. The main models and specifications of the company are as follows:

Model: 750kW
Rated Power: 750kW, wind wheel diameter: 48m/50m
Technology source: technical license (German REpower)
Cumulative production: 3,000 units, 1,400 units produced in 2008
Estimated yield in 2009: 300 units

Model: 1.5MW
Rated Power: 1.5MW, wind wheel diameter: 70m/77m/82m
Technology Source: co-designed with German Vensys and results of the National 863 Scientific and Technological Research Project
Cumulative production: 410 units, 370 units produced in 2008.
Estimated yield in 2009: 2000 units

Sinovel Wind Power Technology Co., Ltd. (state-owned company, industry background: Heavy lifting equipment).

Sinovel is a high-tech enterprise engaged in wind turbine development, design, manufacture and marketing. Headquartered in Beijing, the company has a production base in Dalian. The company introduced 1.5MW wind turbine manufacturing technology from abroad and made mass production. At same time it also developed models adapting to China's operating environ-

ment. Its 3MW wind turbines, installed in the Shanghai Donghai Bridge 100MW offshore wind farm, is co-designed with a foreign consulting firm, the company owns the intellectual property rights of the 3MW turbine. The main models and specifications of the company are as follows:

Model: 1.5MW
Rated Power: 1.5MW, wind wheel diameter: 70m/77m
Technology source: technology license (Germany Fuhrlander)
Cumulative production: 1,650 units, 1,000 units produced in 2008
Estimated yield in 2009: 2,000 units

Model: 3MW
Rated Power: 3MW, wind wheel diameter: 91m/100m
Technology Source: co-design (Austria Windtech)
Cumulative production: 1 unit, 1 unit produced in 2008
Estimated yield in 2009: 40 units

Dongfang Steam Turbine Co., Ltd. (state-owned company, industry background: power generation equipment).

Dongfang belongs to China Dongfang Electric Corporation. The main products are steam turbines. The company's strategy is to produce equipments for thermal power, nuclear power, wind power, gas power and solar power simultaneously. After several years of quick development, its thermal power entered into the stable period of development. The wind power equipment is in its new economic growth point. The company signed a 1.5MW wind turbine technology transfer contract with German REpower in 2004 and made a mass production in 2006. At the same time the company also cooperated with foreign design firms to develop 2.5～3MW wind turbines so that it can own the independent intellectual property rights. The main model and specifications of the company are as follows:

Model: 1.5MW
Rated Power: 1.5MW, Wind wheel diameter: 70m/77m
Technology Source: Technical License (German REpower)
Cumulative production: 1,000 units, 1,000 units produced in 2008
Estimated yield in 2009: 1,140 units

Zhejiang Windey Wind Power Engineering Co., Ltd. (state-owned company, industrial background: electrical and mechanical engineering)

Windey has engaged in wind power technology research and product development for 30 years. The company's main business is producing and marketing of grid-connected wind turbine, components and parts and also involved in consulting service such as wind farm planning, designing and installation. The company introduced 750kW wind turbine technology from abroad, undertaking research tasks of national science and technology programs, including independent R&D of MW-level wind turbines. The company established its production base in Hangzhou and produced 1.5MW wind turbine prototype in 2008. The main model and specifications of the company are as follows:

Model: 750kW
Rated Power: 750kW, wind wheel diameter: 49m/50m
Technology Source: technical license (German REpower)
Cumulative production: 450 units, 320 units produced in 2008

Model: 1.5MW
Rated Power: 1.5MW, wind wheel diameter: 70m/77m
Technology Source: independent research and development (with collabration by GH Company from UK).
Cumulative production: 1 unit, 1 unit produced in 2008
Estimated yield in 2009: 900MW for both models

Shanghai Electric Wind Power Equipment Co. , Ltd. (stock company, industry Background: power generation equipment).

Shanghai Electric Wind Power Equipment Co. , Ltd is a joint venture of Shanghai Electric Group Co. , Ltd. and China Huadian Engineering Group Co. , Ltd. It specialized in the large wind turbine designing, manufacturing, marketing, technical advising and after-sales service. Headquartered in Shanghai Zizhu High-tech Park, the company has two assembling factories located in Shanghai Minhang Economic and Technological Development Zone and Tianjin North Star Science and Technology Park.

The company introduced 1. 25MW wind turbine from EU Energy Group in UK and co-designed the 2MW turbine with German Aerodyn company with independent intellectual property rights. The prototype of 2MW turbine has been produced in 2008. The company is developing large-scale offshore wind turbine by itself.

Model: 1. 25MW

Rated Power: 1. 25MW, wind wheel diameter: 64m

Technology source: technical license (UK EU Energy Wind, the former German Dewind brands)

Cumulative production: 170 units, 150 units produced in 2008

Model: 2MW

Rated Power: 2MW, wind wheel diameter: 80m

Technology source: co-design (Germany Aerodyn)

Cumulative production: 1 unit, 1 unit produced in 2008

Estimated yield in 2009: 500 units for both models

2. 3. 2. 2 Wind Turbine Component Manufacturing

Some domestic manufactures have developed some key component in accordance with the requirements of entire wind turbine manufacture. Foreign companies also set up wind turbine component factories in China and are in-

creasing their production capacity. Currently, key bearings, inverters and control systems are in short supply.

(1) Leading Manufacturers of Blades

There are 35 domestic and joint ventures blade manufactures in China, accounting for 83% of the total, mainly including CNAC Teng-hui, Zhongfu Lianzhong, Shanghai Fiber Reinforced Plastic (SHFRP), Changqian Xinyu, Tianjin Dongqi, Baoding Huayi, Zhongcai Keji, Tianjin Xinfeng, Tian-Qi Shares, Guangdong Mingyang, Changzheng Electric, Guodian Lianhe, Tianwei Fengdian, Shanghai Ailang, Hande Fengdian, Hanwei Energy etc..

There are six foreign-owned enterprises, accounting for 17%, mainly including LM (Tianjin), Vestas (Tianjin), Gamesa (Tianjin), Suzlon (Tianjin), Nordex (Dongying) and TPI (Taicang).

(2) the leading manufacturers of gear boxes are DHI. DCW, Chongqing Gearbox, Nanjing Gearbox, Deyang Erzhong, Hangzhou Advance Gearbox, Jake (Germany) and so on.

(3) the leading manufacturers of generators are Dalian Tianyuan, Yongji Motor, Zhuzhou Motor, Nanjing Turbo, Sichuan Dongfeng, Shanghai Nanyang, Shanghai Electric, Lanzhou Electric, Xiangdian Gufen, VEM (Germany) and so on.

(4) the leading manufacturers of control systems are Gold Wind, Windtec (Austria), Mita (Denmark), SEG (Germany) and so on.

(5) The leading converter manufacturers is Beijing ABB, VERTECO (Finland), Windtec (Austria) and so on.

2.3.2.3 Wind Power Manufactures are Facing Fierce Competition

There are more than 20 companies entered into the entire wind turbine manufacture in 2008, making the number over 70. Among them, about 30 companies had their products installed into wind farm. The expansion of wind turbine production capacity alleviated the short supply of wind power equipment in the past two years in Chinese market and the white-hot competition of wind power equipments is approaching. In the next a few years, the demand for wind power equipment will be stable or of slow growth because

the market is limited, even if the total installed capacity of wind power reach 20GW in 2010 and 100GW by 2020, which mean the new installed capacity will be 8GW per year. At present, Gold Wind, Sinovel and Dongfang already have 4GW manufacturing capacity, which means that more than 60 other companies will compete another 4GW market capacity.

2.3.3 The Policy and Main Problems of Wind Power Industry

2.3.3.1 Policy

National Development and Reform Commission approved feed-in tariffs for the areas other than the 72 concession wind power projects in six provinces in 2008. The feed-in tariffs are in three grades, namely, 0.51, 0.56 and 0.61 Yuan per kilowatt-hour. Compared with the bidding tariffs of previous concession projects, these approved tariffs are more reasonable. Local wind energy resources, costs of transportation, costs of equipment and installation and other factors were taken into account. So they are appropriate and will benefit the wind power industry.

Following the policy of collection 0.1 cent per kWh of renewable energy fund from public consumption of electricity in 2006, another 0.1 cent per kWh was added in 2008. So currently 0.2 cent per kWh of renewable energy fund is collecting from public consumption of electricity. The fund is mainly used to cover the power price difference between thermal power and wind power.

There are two new policies related to wind power industry issued in 2008. On April 14, 2008, "The notice on Import Tax Adjustment of High-power Wind Turbine, Key Components and Raw Materials" was issued by Ministry of Finance. Starting from January 1st, 2008, the import tax and import VAT of key components and raw materials of high-power wind turbine will return to domestic enterprises to encourage them to develop and make entire high-power wind turbine. The tax rebates will be taken as an investment of national capital and must be used for R&D of new products as well as the capacity-building of independent innovation.

On August 11, 2008, "The managing measures of wind power equipment Industrialization fund" was issued by Ministry of Finance, adopting a wind power supporting measure of "Yijiangdaibu". The approach is that a subsidy of 600 Yuan per kW will be paid for the first 50 sets of MW level wind turbines to the manufacture. These 50 turbines must have the certification of CGC (China General Certification) and must have been installed in the field and put into operation. That means the industrialization must be market-accepted. This is the first national finance subsidy for renewable energy products and is the first link product certification as a necessary condition with government subsidy. The managing measures also requires that all turbine companies must adopt domestic made blades, gear boxes and generators and share subsidy with their component suppliers in accordance with the cost proportion.

The fact that the government accept winds power product certification and provide subsidy will significantly promote wind power equipment industry to digest the introduced technology, enhance the ability of independent innovation and nurture the core technology of its own.

2.3.3.2 Main Problems

(1) The technology of wind resource assessment and wind turbine micro-sitting is difficult to accurately estimate the power production. The actual sold wind power is often less than the estimated value in the feasibility study. It is needed to improve the accuracy of macro wind energy resource assessment and economic exploitable reserves of wind energy resource.

(2) The industry of wind power equipment manufacturing has not yet mastered the core technology of design of wind turbine. They need to accumulate on-site operating experience and digest the imported technology. If calculate the wind power cost of kWh for its 20-year lifetime according to its current performance, it does mean the bigger the wind turbine is, the lower it costs. All the domestic enterprises are developing MW and multi-MW level wind turbines, but they cannot make variable speed and pitch wind turbines which are less than a MW but has a better performance-price ratio. This segment of market is still dominated by foreign enterprises. A national level

public wind turbine testing field is needed, where wind turbine manufactures can win position to do their prototype testing and improve their overall design capacity.

(3) The power grid has become a major bottleneck of wind power development, especially in 2008. Among the wind farms already in operation, due to the load limitations, some wind farms can only feed part of power generated into the grid. Despite that it's written in RE Law that the renewable energy has the priority to access the grid, the grid companies are actually difficult to implement. When wind turbine installed capacity was small and wind turbines were distributed around the grid, grid connection was not a big case. But in recent years, the growth of wind power installed capacity increase quickly, and many of them located in northwest and northeast of China where is the edge of grid, so the grid access has become a big problem.

National Development and Reform Commission issued "Renewable Energy Median and Long-term Development Plan" in September 2007. The planed target of wind power in 2010 is 5GW. But only in 2008, the new installed wind power capacity had reached 6GW, and the cumulative installed capacity exceeded 12GW. While the power grid was developed in accordance with the Plan, so it cannot catch up with the quick development of wind power.

Because of the intermittent characteristics of wind power, the grid access of wind power is a challenge for grid companies. Many technical and management problems are urgently to be address. Also, in order to maintain the smooth operation of the grid, the power quality of wind farms must meet higher standards.

The Chinese power grid enterprises are monopolistic in nature, they purport to assume greater social responsibility. But for its grassroot work units, due to the instability of wind power, they have to provide additional service, which increased the cost of operation and management and bring additional risks. It urgently need to establish an effective incentive mechanism, converting attitude of grid company from reactive to proactive to accept wind power. Otherwise, the more wind power capacity installed, the more resistance of grid access will have.

2.4 Wind Energy Product Testing and Certification System

(1) With the support of a Sino-German cooperation project, the New Energy Institute of China Electric Power Research Institute purchased test equipments of wind turbine power characteristics and formed power curve measurement capability.

(2) China Classification Society already has formed the capability of gear boxes, generator certification.

(3) China General Certification Center has issued some certification of wind turbine design evaluation, such as the certification of wind turbine design evaluation of Sinovel 1.5MW wind turbine, and is setting up its wind turbine type certification capability.

(4) For those wind turbine models co-designed by domestic companies and foreign engineering consulting firms, usually, they will apply Germany Lloyd's Register or Denmark DNV design evaluation certification to obtain bid qualification in the domestic market, and then apply domestic certification.

2.5 Financial Crisis' Impact on Chinese Wind Power Market

The impact of financial crisis on the global economy continues. Due to the slowdown in global demand, the declined prices of raw materials will further reduce the cost of wind turbine. Foreign manufacturers will increase its promotion effort and compete with Chinese companies. This will relieve the relationship between supply and demand to some extent and shorten the wind farm construction period, which will help wind power industry to develop healthily.

The global financial crisis does not affect the quick development Chinese wind power industry, to some extent, it will provide an opportunity for development. On one hand, it will accelerate the integration of Chinese manufacturing enterprises, survival of the fittest; on the other hand, banks have reduced the interest rate, so financing cost of wind power developers reduced. The slowdown of thermal power encouraged power companies to invest in wind farm construction projects.

3 Solar Energy

3.1 Solar Resources in China

China solar radiation resources is rich. According to China's solar energy resource distribution during 1971～2000, as well in order to facilitate the development and utilization of solar energy resources, the solar energy resource areas in China can be divided into four regions, as shown in Fig. 6, by the spatial distribution of total annual solar radiation, which is also the method of the first-class zoning. Four regions of solar radiation resources are shown in Table 9 and Table 10.

Fig. 6 Solar Radiation Resources Distribution of China
(Ignored Dongsha, Nansha, Xisha Islands)

Table 9 Solar Radiation Resources Distribution of China

Title	Resources code	Indicator [kWh/(m² · a)]	Percent of national territory
Abundant	I	≥1,750	17.4%
Very rich	II	1,400～1,750	42.7%
Rich	III	1,050～1,400	36.2%
Average	IV	≤1,050	3.70%

Table 10 Solar Resources Region Distribution of China

Title	Sign	Index [kWh/(m² · a)]	Percent of national territory	Region
Abundant	Ⅰ	≥1,750	17.4%	Main parts of Tibet, south parts of Xinjiang, Qinghai, Gansu and west parts of Inner Mongolia
Very rich	Ⅱ	1,400～1,750	42.7%	Main parts of Xinjiang, Qinghai, east parts of Gansu, Ningxia, Shanxi, Shanxi, Hebei, northeast parts of Shandong, east parts of Inner Mongolia, southwest parts of the Northeast, Yunnan, and west parts of Sichuan
Rich	Ⅲ	1,050～1,400	36.3%	Heilongjiang, Jilin, Liaoning, Anhui, Jiangxi, south parts of Shanxi, northeast parts of Inner Mongolia, Henan, Shandong, Jiangsu, Zhejiang, Hubei, Hunan, Fujian, Guangdong, Guangxi, east part of Hainan, Sichuan, Guizhou, southeast parts of Tibet and Taiwan
Average	Ⅳ	<1,050	3.6%	Middle part of Sichuan, north part of Guizhou and northwest part of Hunan

Ⅰ Regions with abundant solar radiation resources are:

Most part of Tibet, southern part of Xinjiang, Qinghai, Gansu and western part of Inner Mongolia. The amount of annual solar radiation in these areas are more than 1750 kWh/m^2, and the ratio of the maximum and the minimum number of the days available monthly is smaller, with more stable annual change, which is the best regions for solar radiation resources using.

Ⅱ Regions with very rich solar radiation resources are:

North part of Xinjiang, Northeast China, eastern part of Inner Mongolia, North China, north part of Jiangsu, the Loess Plateau, Qinghai, east part of Gansu, western Sichuan to the Hengduan Mountains, as well as Fujian, Guangdong coastal areas and Hainan Island.

These areas are next to the abundant solar radiation regions, and the amount of annual solar radiation can reach to 1400-1750kWh/m^2. The annual change in the number of available hours is still relatively stable, but in the Hengduan mountains and along the southeast coastal area, the ratio of maximum and minimum number of available days has been over 2.0, and the seasons not being conducive to solar energy use significantly increased compared to abundant areas.

Ⅲ Regions with rich solar radiation resources:

The amount of annual solar radiation in rich solar radiation resources region is 1050-1400kW • h/m^2, which is mainly distributed in the hilly area in southeast China, the Han River basin, as well as Sichuan, Guizhou, the western part of Guangxi, etc. In these regions, the ratio of the maximum and minimum number of available days all over 2.0, that it is, the number of the available days changed a lot in one year, and the season existed the minimum isn't conducive to solar energy use.

Ⅳ Regions with average solar radiation resources:

The solar radiation resources in Sichuan and Guizhou are in average and the amount of annual solar radiation is less than 1050 kW • h/m^2. Solar radiation resources in these areas is the smallest in China. In Chongqing, the number of days with sunshine hours over 6 hours is only 1-2. Besides June and July in summer,

the average number of day sunshine hours over 6 hours is about 18, the rest months less than 9 days.

During 1971～2000, the 30-year average amount of total solar radiation is about 1050～2450kW • h/m^2, while these regions have no less than 1050kW • h/m^2(I, II and III band). The areas rich in solar radiation resource are approximately more than 96% of the national territory.

Solar radiation energy, short as the solar energy mainly focus on a wavelength of 0.3～3.0 microns Outside the atmosphere, air quality is defined 0; When the sun vertical incidence to the ground, the air quality is 1, expressed by AM1; Solar incident to the ground, through the atmosphere, ozone absorbs the short-wave, carbon dioxide gas and water vapor absorb the visible and near-infrared part, and scattering dust in the atmosphere decrease the intensity of the sun. In the utilization of solar energy, the sun altitude angle (αs) 41.8° incidence is used for uniform calculation in the world, called air quality 1.5, expressed by AM1.5, solar spectrum of the AM1.5 shown in Figure 5. The solar thermal use and solar photovoltaic conversion efficiency is high; China has abundant solar energy resources, for the 30-year average of 1971～2000, each year the sun radiation amount on our 9.6 million km^2 of land, is equivalent to 1.7 trillion tce (tons of standard coal); The life of solar energy is about 3 billion years, so it is inexhaustible to the human.

3.2 Solar PV

3.2.1 Solar PV Market in China

3.2.1.1 Historical Evolution of China's PV Market

Into the 21st century, China's PV market began to have a relatively fast development driven by the government, and a lot of national plans have been implemented, such as the "Power Supply Project for Un-electrified Counties in Tibet", "China Brightness Program", "Brightness Program in Arli Dis-

trict, Tibet", "Township Electrification Program" and " non-electric power construction in the region ", etc. During the period from "Ninth Five-Year Plan" to "Eleventh Five-Year Plan", several demonstration projects have been carried out, such as urban grid-connected photovoltaic power generation and large-scale desert plant grid integration. By seeking international assistance, the Chinese government also carried out a number of international cooperation programs, to promote the use of photovoltaic power generation in rural electrification. China's "Renewable Energy Law" was entered into force in 2006, government departments (National Development and Reform Commission, Ministry of Science and Technology, Ministry of Construction, Ministry of Finance, Ministry of Information Industry, Ministry of Agriculture, etc.) are actively promoting the application and popularization of photovoltaic power generation, and start a number of photovoltaic power generation projects. After the success of the Olympic Games, in order to carry out the commitment of "Green Olympics", Beijing has built a number of building-integrated photovoltaic projects and 135,000 solar street lamps, with a total power of 10MW.

In accordance with the statistics from www.chinabidding.com, in 2008, see in Table 11, and Fig. 7, there are a total of 175 photovoltaic power generation projects through an open tender. The total installed photovoltaic power produced by completed projects reached 30MW, and it is estimated that about 10MW of photovoltaic projects are without public bidding. China PV system installation capacity is about 40MW totally in 2008.

By the end of 2008, China's cumulative installed PV power generation has reached 140MW. The market development of China PV power generation since 1980 are shown as Table 12 and Fig. 8.

Table 11 China PV Tender Statistics in 2008

Tender Projects in accordance with the allocation of PV power market in 2008					
Market	Rural electrification	Communication and industry	Grid connected generation	Solar energy lamps and etc.	Total
Installed power(kW)	747.6	4085	17942.4	7536.6	30311.6
Num. of project	6	17	32	120	175

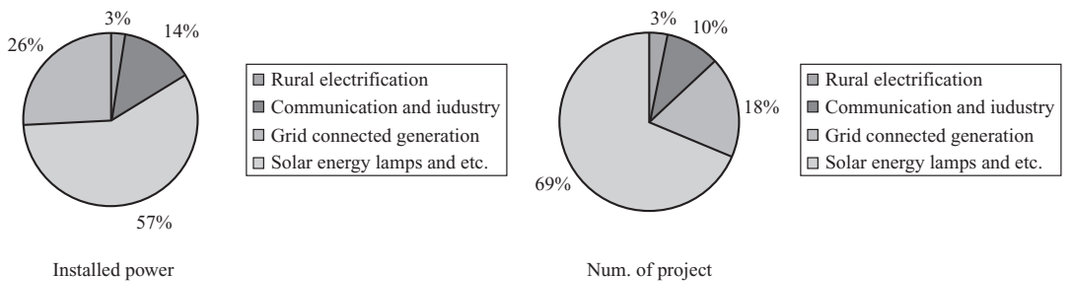


Fig. 7 Distribution of China PV tenders in 2008

Table 12 China's domestic PV market development since 1980 (kW)

Year	1980	1985	1990	1995	2000	2002	2004	2006	2007	2008
Annual Installation	8	70	500	1550	3300	20300	10000	10000	20000	40000
Accumulative Installation	16.5	200	1780	6630	19000	45000	65000	80000	100000	140000

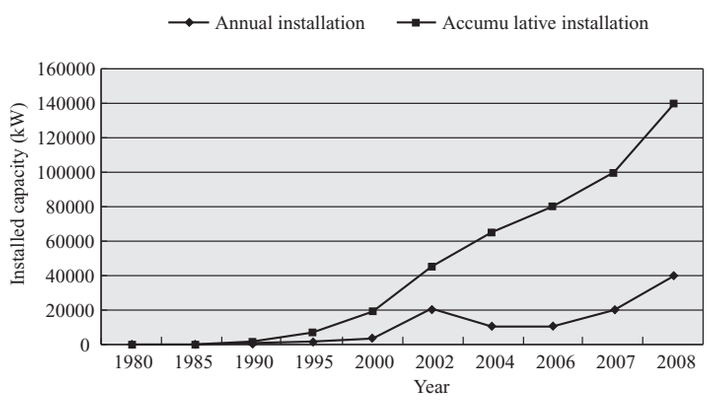


Fig. 8 The annual and cumulative installed capacity of China's domestic market since 1980

While China's output of solar cells have ranked first in the world for 2 consecutive years, 98% for exports, only 2% for the domestic installed capacity. China's photovoltaic industry totally dependents on the international market, so China now need to develop the domestic market immediately.

3.2.1.2 China's Potential market for PV Power Generation

(1) potential market for rural electrification

By the end of 2005, China still had about 2.7 million households, 12 million people without electricity, of which 100 households without electrici-

ty need to use the complementary generating system of PV and wind-light to solve the problem by 2020.

If estimated according to poverty criteria (installed 200Wp per household, annual 200kW·h electricity consumed by per household), the total installed capacity is expected to 200MWp; If estimated by the city power standard in remote areas (annual 1000kW·h electricity consumed by per household), then the potential market capacity is 1000MWp (1GWp).

(2) building integrated photovoltaic systems (BIPV)

At present, about 70% of the world's solar cells are used for grid systems, mainly in combination with the construction method (BIPV) installed in the city's architecture. According to China's long-term development plan, China's total installed capacity of solar cells used for BIPV will reach 50MWp by 2010; and to reach 1000MWp by 2020. China now has approximately 4.0 billion m^2 roof areas, together with the Southern façade, the available area will be approximately 5.0 billion m^2. If 20% is used to install solar cells, the installed capacity can reach 100GWp.

(3) large-scale photovoltaic (LS-PV) power station in desert

According to China's long-term renewable energy development plan, several desert test stations with the capability of 1～10MWp will be built in Gansu, Tibet and Inner Mongolia before 2010 (total installed capacity of 50MWp). They will be further promoted during the period 2010 to 2020, and the cumulative installed capacity of large-scale desert solar power plants will reach 200MWp by the end of 2020.

3.2.2 China PV Industry Chain and Present Status of Technology

3.2.2.1 Polycrystalline Silicon Feedstock

By now, crystalline silicon solar cells have been the mainstream of commercialization of PV power generation in the development of PV technology. More than 90% of the solar cells in the international market are produced by high-purity polycrystalline silicon. As the basic materials of solar cell production -preparation of high-purity polycrystalline silicon has become the most important one of the links in photovoltaic industry chain.

High-purity polycrystalline silicon materials can be divided into micro-elec-

tronics-grade silicon and solar grade silicon, respectively used in the production of the semiconductor chips and the crystalline silicon photovoltaic cells. Since 2006, the photovoltaic industry has become the biggest consumer of high-purity crystalline silicon materials, more than microelectronics industry.

(1) Graded according to the purity of silicon raw material (impurity)

Metallurgical grade silicon (MG) purity: 90%～99%(one 9-two 9s), $ 2～4USD/kg

Solar grade silicon (SG) of purity: (six 9s-eight 9s), $ 50～100 USD/kg

Electronic-grade silicon (EG) purity: (nine 9s-eleven 9s), $ 80～200USD/kg.

(2) Preparation of high-purity polysilicon

① Chemical purification

Siemens-Vapor Deposition Reaction

A silicane thermal decomposition method

② The new solar-grade silicon production process

Wacker: fluidized bed method (silicon grains+$SiHCl_3$)

TOKUYAMA: gas -liquid deposition ($SiHCl_3$+catalyst)

REC (ASiAI): silicane—fluidized bed

Kawasaki: refined metallurgical grade silicon purification

Elken: pyrometallurgy—hydrometallurgy—caking purification

Norway: high purity quartz sand and carbon black—System pellets—plasma furnace to restore—Directional Solidification

The "improved Siemens—hydrogen reduction of trichlorosilane" is still the main production technology in the international high-purity polysilicon production (about 80% of the global yield). The comprehensive energy consumption of high-purity polysilicon are about 130～250kW·h/kg silicon material.

Pulled by foreign PV market demand, China's polysilicon industry has developed rapidly, with rapid technological progress. Some enterprises improved the advanced technology of Siemens through the introduction, digestion and absorption of Europe and the United States and other countries, and made continuous innovation in polysilicon production practice. China's high-purity polycrystalline silicon purification technology has reached the international advanced level.

China's polysilicon production was only 300 tons in 2006, of which 200 tons from Luoyang Zhonggui, 100 tons from Emei semiconductor. In 2007, Leshan Xinguang Silicon Industry 1,260 tons/year production line, Luoyang Zhonggui 1,000 tons/year production line, Xuzhou Zhongneng 1,500 tons/year production line, and Wuxi Zhong Cai 300 tons/year production line are all put into operation one after another, so that the total output in 2007 reached 1,100 tons.

In 2008, in addition to these enterprises need to expand production, as well as a number of new enterprises put into operation, our high-purity polysilicon production reached 5,000 tons, and self-sufficiency rate of polysilicon materials is 25%. Table13 shows China's polysilicon production capacity and output during 2006 to 2008.

Table 13 2006～2008 Polysilicon production capacity and yield in China

Company	2006(ton)		2007(ton)		2008(ton)	
	Capacity	Yield	Capacity	Yield	Capacity	Yield
Emei Semi.	200	100	700	200	700	400
LuoYang Zhonggui	300	200	1,000	550	3000	1,000
Sichuan Xinguang	1,260	0	1,260	210	1260	800
Shanghai Lingguang	40	0	40	20	40	50
Wuxi Zhongcai			300	20	300	300
Xuzhou Zhongneng	1,500	0	1,500	100	4000	1,800
Chongqing Daquan					2000	50
Others					8700	600
Total	3,300	300	4,550	1,100	20000	5,000

Table 14 2008 Polysilicon yield in China

Company	Yield(ton)	Company	Yield(ton)
Xuzhou Zhongneng	1,800	Sichuan Yongwang	50
Luoyang Zhonggui	1,000	Qinghai Asia silicon industry	50
Sichuan Xinguang	800	Ningxia Shizuishan	50
Emei Semiconductor	400	Chongqing Daquan	50
Wuxi Zhongcai	300	Yangzhou Shunda	30
Sichuan Yongxiang	100	Hushi Shenzhou	20
Shanghai Lingguang	50	Others	300
Total		5,000	

3.2.2.2 Crystalline Silicon Ingots/Wafers

Silicon ingot slice is pre-proceduced for producing crystalline silicon solar cells, shown in Fig. 9. 65% of the crystalline silicon cell modules' cost comes from silicon wafers (silicon feedback included), along with the continued high cost of silicon feedback, silicon ingot cutting process plays a more and more important role in silicon wafer production. To save silicon feedback, to reduce silicon wafers costs and to improve production efficiency has become the focus of the current silicon wafers manufacturing industry, by continuously upgrading technology of silicon preparation. Fig. 10 shows the trends in consumption of silicon feedback forecasted by EPIA, thus it can be projected out that In 2008, about 9 tons of silicon feedback (9g/Wp) will be consumed per MWp of PV cells in China.

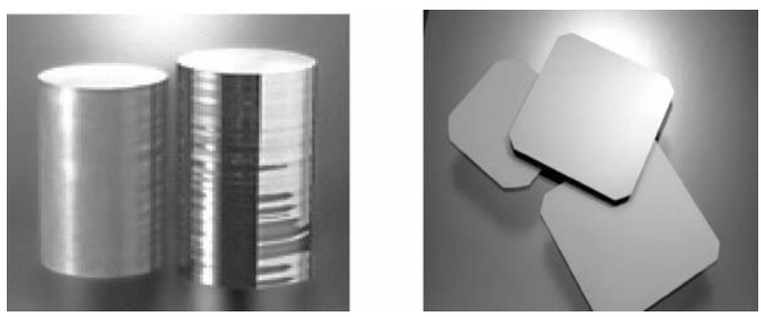
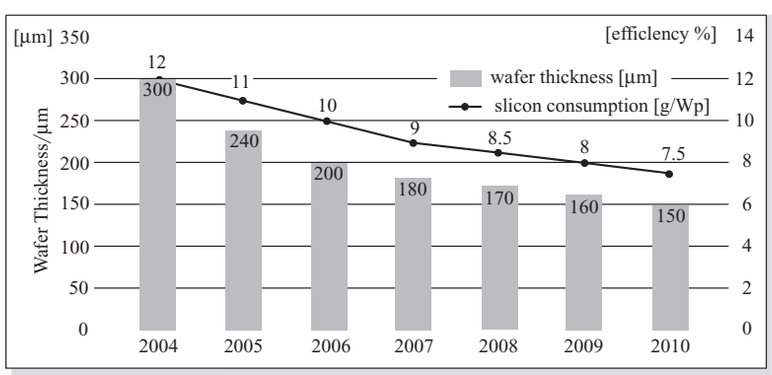


Fig. 9 single crystalline silicon rods/wafers



Source: Solar Generation-V 2008, EPIA, Greenpeace.

Fig. 10 Trends in solar cell silicon feedback consumption (g/Wp)

(1) Pulled single crystal silicon

A single crystal can be produced by two ways: crucible method and zone melting. China has been able to produce 6-inch, 8-inch and even 12-inch single crystal silicon in Czochralski silicon crystal furnace.

(2) Multicrystalline silicon ingot

The earliest international methods are ingot casting method, directional solidification and heat exchange method. For casting method, crystal grows fast, but the grain is small, with more complex devices, so it is being phased out; American company GT's heat exchange method has gradually shifted directional solidification method; While the directional solidification method is the mainstream approach for the recent commercial ingot furnaces (see as Fig. 11).

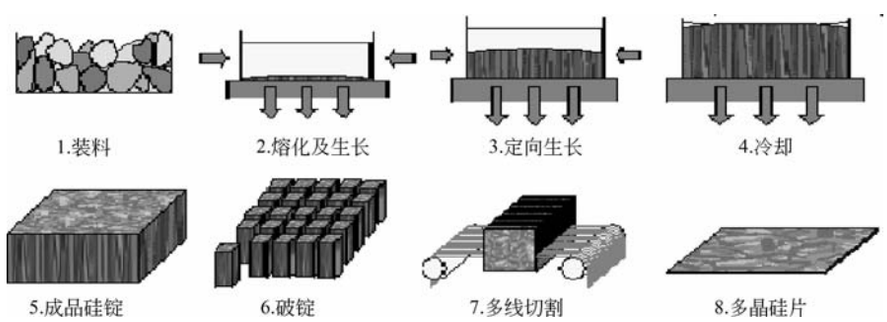


Fig. 11 Manufacturing process of polysilicon ingots and silicon wafer

Multicrystalline silicon ingot is a very important way to reduce the cost of technology. The technology eliminates the expensive pulling process, can also use the lower-purity silicon as the furnace charge, and materials and energy consumption are more savings. Therefore, multicrystalline silicon ingot has replaced Czochralski silicon at present and becomes the mainstream products in the international market.

In recent years, large ingot process is mainly towards the direction of development. Technologically advanced companies produced multi-ingots of 55cm×55cm, weight about 150kg. Currently, ingots of 65cm×65cm with the weight of 250kg have also been cast successfully. Large ingot process can effectively reduce the cost of crucible and power consumption, and also is conducive to large-scale production of silicon ingots; Meanwhile, through

process optimization and improvement of crucible materials, defects and impurities, oxygen, carbon content all reduced, thereby enhancing the quality and utilization of silicon ingots.

To satisfy the market need, the development of China-made Polysilicon Cast furnace is speeding up, the situation of relying on exclusively import for this equipment is changing. There are several enterprises, including China electronic technology Co. 48 Unit, Jingyuntong, have already developed good quality 240～270kg and 400～450kg series products and begin to batch production and sales.

(3) Wafer Processing

Silicon wafer cutting is the key technology of production, in which the cutting quality and size directly affect follow-up production of the entire industry chain. Multi-wire-slicing, as an advanced cutting technology, has gradually replaced the traditional inner circle cut into the main processing method of silicon wafers slicing. At present, many enterprises using multi-wire-slicing technology, silicon thickness of 180-200 microns can be achieved, and energy consumption is about 220～300kW·h/kWp. Using the most advanced multi-Wire-slicing technology, silicon thickness can reach to 180 microns, 400 kg of silicon ingot can be cut more than 13,000 pieces. With the advances in technology, silicon wafer is expected to further thinning. Table 15 shows the technical trend of ultra-thin silicon wafer.

Table 15 Technical trend of ultra-thin silicon

Year	2004	2005	2006	2007	2008	2009	2010
Wafer Thickness(μm)	320	270	220	200	180	160	150

Currently dicing saw equipment depends on import. To satisfy market need, the development of China-made dicing saw is speeding up, there are several enterprises are undertaking investigation of dicing saw equipment, a company in Shanghai is testing their prototypes, products from a company in Gansu has passed certification.

At present, about 60 companies are developing the production of silicon

ingots and silicon wafers, in 2008 the amount of production reached 25,000 tons, production capacity can reach 30,000 tons.

3.2.2.3 Solar Cell Manufacturing

(1) Crystalline silicon solar cell manufacturing

Crystalline silicon solar cell is made by the process of diffusion and junction in the single crystal or polycrystalline silicon technology. Commercial crystalline silicon solar cell production process is more or less the same, including: damage layer removal, suede production, electrodes printing and sintering.

To meet the PV market in the world, in recent years, China's solar cell industry has maintained rapid growth momentum. Despite of raw material constraint, new businesses continue to add to the PV industry ranks the past two years. According to statistics, by the end of 2008, enterprises engaged in solar cell production reached 65. In accordance with the calculation in power equipment, solar cell production capacity reach 4,000MWp (including amorphous silicon thin-film batteries is about 100MWp).

In battery production, in 2007 the national production is 1,088MW, more than Europe and Japan, ranking first in the world; in 2008 China's solar cell production reach to 2,600MW, accounting for 32.9% of the world's total output(7,900MW), ranking first in the world with total superiority.

Table 16 2008 solar cell production yield of China's main PV company(MW)

Company	Yield	Company	Yield
Wuxi Suntech power Co. ,Ltd	497.5	CEEG	110.9
Tianwei yingli new energy resources Co. ,Ltd	281.5	Canadian Solar Inc	108.0
Hebei Jing'ao	277.0	Changzhong Yijing	99.7
Changzhou Trina solar Co. ,Ltd	209.0	Ningbo Solar electric Co. ,Ltd	97.0
Jiangsu Linyang solarfun Co. ,Ltd	189.0	Jiangsu Junxin	65.3

Continued

Company	Yield	Company	Yield
Eoplly New Energy Technology Co. , Ltd	40. 0	Changzhou Shengshi Electron Technical Co. ,Ltd	10. 6
Changzhou Shunfeng	30. 0	Yunnan Tianda photovoltaic	50. 0
SunLink PV	24. 0	Others in Zhejiang	50. 0
Jiangsu Tianbao PV Energy	18. 0	Shenzhen	50. 0
Wuxi Shangpin Solar	16. 2	Others	376. 3
Total		2600MW	

(2) Amorphous silicon thin-film solar cell manufacturing

In 2007, the add production capacity of China's thin-film cell reach 80MWp. There are a large number of enterprises which are planning and introducing a higher technical level product-line of non-stacked micro-batteries (a-Si/μc-Si). Such as Suntech Power (Shanghai) and the Hebei Xinao are introducing American Applied Material's non-double-junction micro-battery production line with the production capacity of 40-60MWp, while Tianwei Group are introducing Oerlikon's 50MW amorphous silicon cell production line. Fujian Golden Sun cooperated with Nankai University and other units to establish technology development center, self-manufacturing equipment and expanding production capacity, etc. After these cells product-line built up and productive capacity formed, China's thin-film solar cell industry will be improved to a new technical level.

Currently a-Si solar cell attracts attention because of its low cost, good looking appearance and good low light property. But it still facing challenges like low efficiency, efficiency decay, short lifetime compare to crystalline silicon cell and low market acknowledgement. Also thin film manufacturing technology is still fast improving, equipment is not stabilized, initial investment is much higher, therefore the investment risk is higher than crystalline silicon cell production line, thus a-Si solar cell investment requires thorough research, understanding and careful analysis.

Table 17 China's amorphoas silcon solar cell production capacity and yield (2008)

Company	Production	Capacity	Yield
Shenzhen Topray Solar Co. ,Ltd	a-Si	25.0	12.0
Shanghai Suosaisi New Energy Technology Co. ,Ltd.	a-Si	20.0	6.0
Shenzhen Trony Solar Holdings Co. ,Ltd.	a-Si	6.0	5.0
Beijing Shihua Innovation Technology Co. ,Ltd.	a-Si	15.0	4.0
Tianjin Jinneng Solar Cell Co. ,Ltd.	a-Si	2.5	2.5
Shenzhen Qingfeng PV Technology Co. ,Ltd.	a-Si	1.5	1.5
Shenzheng Minghuan Solar Co. ,Ltd.	a-Si	2.0	2.0
Fujian Goldensun	a-Si	12.0	2.0
Zhejiang Fusheng Solar Co. ,Ltd.	a-Si	1.5	1.0
Shenzhen Hengyang PV	a-Si	1.2	1.0
Haerbin Gerui Solar Co.	a-Si	1.0	1.0
Heilongjiang Hanker New Energy Co. ,Ltd.	a-Si	1.2	1.0
Nantong Qiangsheng Solar PV Co. ,Ltd.	a-Si	25.0	2.0
The Bulletin of Sunvim Group Co. ,Ltd.	CIGS	60.0	Begin in 2009
Bengbu Polar PV Co. ,Ltd.	a-Si	12.0	5.0
Hebei Xin'ao Solar	a-Si	60.0	Begin in 2008
Shanghai Shangde	a-Si	40.0	Begin in 2009
Baoding Tianwei Thin-film Cell(Oerlikon)	a-Si	50.0	Begin in 2009
Best Solar(LDK)	a-Si	1,000.0	Begin in 2008
Total		1,335.9	46

3.2.2.4 PV Module Production

Crystalline silicon PV module manufacturing is to interconnect the single crystalline silicon solar cells, packaging. It can protect the electrode contacts and prevent the interconnecting wire from erosion, to avoid battery broken. The quality of module production directly impacts the service life of crystalline silicon PV modules.

At present, China PV module production industry is the most important link in the entire PV industry chain, with the most mature production technology, equipment of the highest localization rate, the lowest threshold

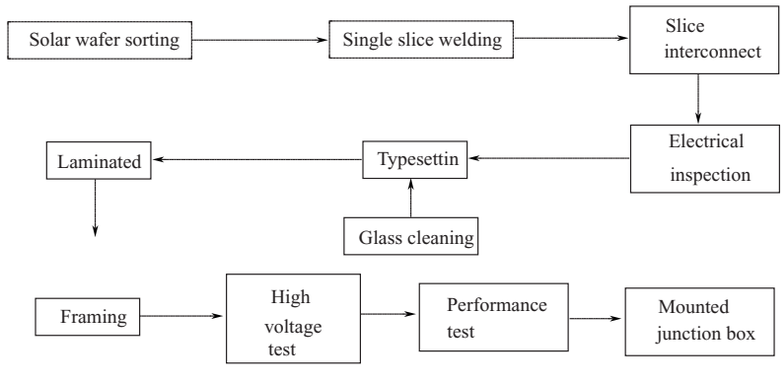


Fig. 12 Solar module production process

practitioners, the largest number of engaged in enterprises, the fastest expansion and the largest output. In the PV industry chain, module production needs low investment and short construction periods. Due to low technical and financial threshold, by taking full advantage of low labor costs, China's PV module production industry develops the fastest. According to incomplete statistics, there are more than 300 module production companies in China, in 2007 module production capacity of 3,800 MWp, in 2008 module production capacity of 5,000 MWp, yield of 3,000MWp.

As China's domestic PV market is not large-scale launch, the majority of domestic PV modules are exported overseas, mainly to Europe and America. At present, China Excellent Enterprise's PV module production technology with the international synchronization, at the international advanced level, Energy consumption can reach 44kW · h/kWp, and most of the equipment already achieved the localization.

3.2.3 Economic Analysis of China's Photovoltaic Power Generation

3.2.3.1 Downward Trend of the Cost of Solar Cells and its System

The cost of PV power generation depends primarily on the building of the initial investment, solar energy resource conditions of construction location, quality of photovoltaic power station construction and operational management level and other factors. With the decline in the price of polysilicon materials, solar cell module prices will come down. According to "Solar PV Industry" released by Deutsche Bank in January 2009, how polysilicon material prices affect crystalline silicon solar cells and system prices are as follows:

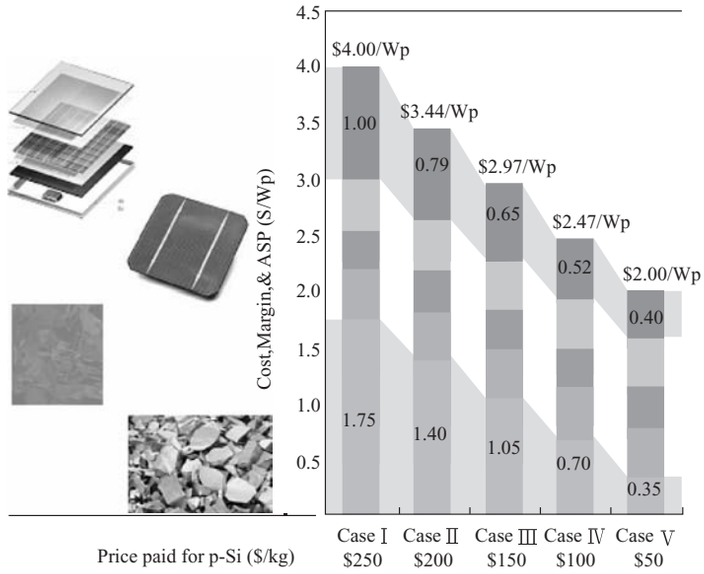


Fig. 13 The price of solar cells influenced by silicon materials

Table 18 Silicon materials' impact on the price of solar module

Silicon materials ($ /kg)	Silicon materials ($ /Wp)	Module cost ($ /Wp)	Gross profit ($ /Wp)	Module price ($ /Wp)
250	1.75	3.00	1.00	4.00
200	1.40	2.65	0.79	3.44
150	1.05	2.32	0.65	2.97
100	0.70	1.95	0.52	2.47
50	0.35	1.60	0.40	2.00

In 2009 polysilicon price remains in the $ 50-60/kg, while the price of crystalline silicon solar module fell to 15 yuan/Wp($ 2/Wp) around.

Table 19 Silicon material price's impact on the initial investment of PV systems

Silicon materials ($ /kg)	Solar cell price ($ /Wp)	System cost ($ /Wp)	Gross profit ($ /Wp)	System investment ($ /Wp)
250	4.00	6.05	1.15	7.20
200	3.44	5.39	1.03	6.42
150	2.97	4.81	0.92	5.73
100	2.47	4.24	0.81	5.05
50	2.00	3.69	0.70	4.39

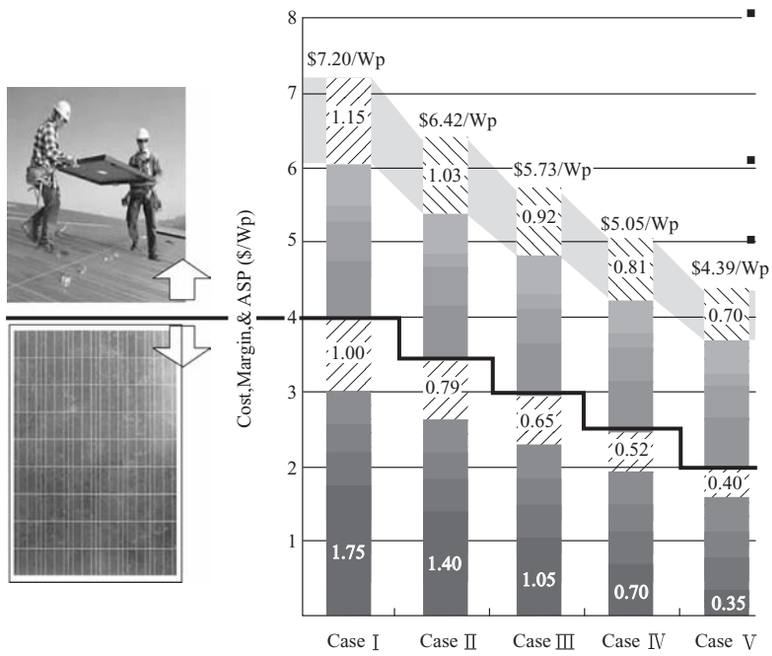


Fig. 14 Silicon materials' impact on the initial investment of PV systems

Once the solar cells price dropped to 14-15 yuan/Wp($ 2.00/Wp), the grid-connected system prices will decrease to 30 yuan/Wp($ 4.39/Wp) around, then PV electricity price in the region with good sunshine radiation (annual operating 1500 hours) could reach 2.4 yuan/(kW · h), and the general area can reach 3.3 yuan in Rizhao of resources(annual running 1,200 hours after taking the efficiency into account). According to the U. S. solar energy pilot project's judgement, once the cost of PV power generation system dropped to 4 U. S. dollars/Wp (about 28 yuan/Wp), its market growth will be explosive(see Figure 15), and the price of 30 yuan/Wp has been very close to this "critical point" .

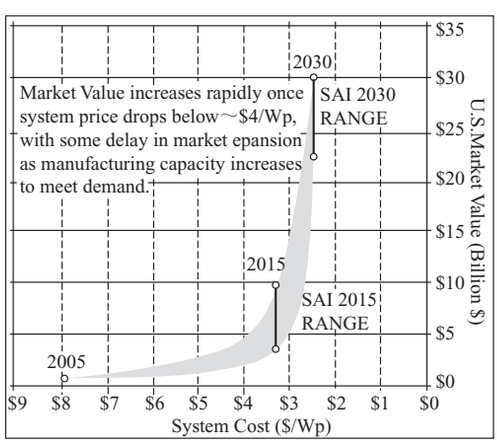


Fig. 15 U. S. solar energy pilot project's forecast of the future PV market

3.2.3.2 Cost Analysis of Crystalline Silicon Solar Cells

According to the various production processes of the solar cell, the market price in early 2008 is as follows:

- Polysilicon feedstock: spot price 200-250 $/kg, calculating by 220 $/kg, Long term contract price $ 50～60/kg;
- Calculating by 9.3g/Wp, every kilo silicon feedstock could produce 107.5Wp solar cell, equal to market spot price 2.05 $/Wp, Long term contract price $ 0.47～0.56/Wp;
- Crystal silicon wafer: 125×125 wafer price is $6/wafer, 2.4Wp/wafer, equal to $2.5/Wp;
- Solar cell wafer: $3.0-3.1/Wp;
- Solar cell module: $3.6-3.7/Wp.

Table 20 2008 Solar cell module market price and increment

Step	Polysilicon	Wafer	Solar Cell	PV module
Sale Price($/Wp)	2.05	2.5	3.05	3.65
Increment($/Wp)		0.45	0.55	0.60
Percentage(%)	56.16	12.33	15.07	16.44

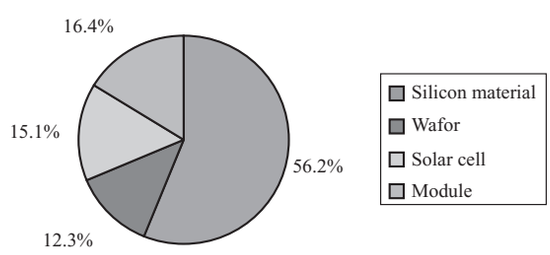


Fig. 16 Solar cell module market price composition

Seen from Fig. 16, silicon feedstock price is 56.16% of PV module price, so it is the main factor affecting the price of solar cells. Obviously as silicon feedstock supply is sufficient, the PV module price will be further reduced. If silicon feedstock price reduce to lower than $60/kg, plus steady decrease of wafer thickness, solar cell efficiency and other related technology improvement, PV module price could reduce to $1-1.5/Wp, then PV electricity generation cost will be competitive to regular energy electricity

generation cost.

3.2.3.3 Cost Analysis of Thin-film Solar Cell

In addition to crystalline silicon solar cells, the international commercialization of thin-film solar cells have also progressed very quickly, already commercialized thin-film solar cells include: dual-junction and three-junction amorphous silicon solar cells, CdTe solar cells, CIGS solar cells as well as Japan's Sanyo HIT solar cell. Before 2004, the new type solar cell and thin-film solar cell accounted for a very small proportion of PV market in the world, less than 4%, but in the past two years the market share of thin-film solar cells increased obviously, in 2006 which accounts for 8%. The price advantage of new type solar cell and thin-film solar cell is much remarkable compared with crystalline silicon solar cell's high price:

Double-junction amorphous silicon solar cells (efficiency 5%-6%): $ 1.5 per/Wp;

Three-junction amorphous silicon solar cells (efficiency of 8%-10%): $ 2.5/Wp;

Other types of thin-film solar cells' price is also significantly lower than the price of crystalline silicon solar cells.

For large-scale production, solar cells made by silicon-based materials (amorphous silicon, HIT, black batteries, etc.) have large development potential. As technology advances, its power generation costs will drop significantly, it was expected that, five years later the thin-film solar and crystalline silicon solar cell will equally share the market.

3.2.3.4 PV System's Power Generation Cost and On-grid Price Calculation

PV on-grid price is decided by the following factors:

- Generating capacity of PV system (kW·h); locally available solar energy resources; system components efficiency; system reliability and power transmission quality; dust, block, line losses and other losses, etc.;
- Investment in the construction of PV power (solar cell, inverter, transportation, installation, etc.);
- Operation and maintenance costs, and local taxes;
- Project construction financing costs (proportion of loans, loan interest rates, repayment method, etc.)

For the independent PV power generation systems, as with the battery, and the daily loading rate is also uncertainty, so the efficiency of power generation would like to add discounts.

(1) pricing principle

- The requirement of price response to the society average cost of PV power generation technology;
- The main investment include three parts: self-funds, government subsidies and bank loans;
- Considering the differences between local resources, to express by annual operating hours;
- Using inverse method to determine the manner of price, which is the tax-inclusive price under the industry benchmark rate of return;
- No change in the price within tax during project life period.

(2) PV on-grid price calculation results

Independent power plant won't have subsidies of "on-grid price", only large-scale grid PV system and city BIPV's on-grid prices are calculated. Grid connected power station in open area's annual effective running time is 1500 hours, considering in accordance with the Northwest regional average resources. BIPV is generally established in the eastern city, according to the effective running time of 1200 hours throughout the year. In addition to the solar radiation resources conditions and the initial investment of systems, the other important financial conditions are set as follows:

Table 21 On-grid price estimate's financial condition

Loan ratio	80%	VAT rate	8.5%
Loan period	15 years	Income tax rate	25%
Loan interest	6.12%	Additional tax rate	8%
Operation period	20 years	Benchmark rate of return	8%
depreciation period	20 years	after-tax internal rate of return	11%～12%
residual value of fixed assets	10%	capital recovery period	10～11 years
annual operating costs	0.1%		

If the initial investment of grid-connected PV power generation system is 36,000 yuan/kW, in the conditions of different annual effective use hours, the price is estimated as follows:

Table 22 PV On-grid price of different generation hours (36,000 yuan/kW)

Effective hours	Price	Effective hours	Price
1000	4.45	1500	3.05
1100	4.20	1600	2.85
1200	3.85	1800	2.55
1300	3.50	2000	2.30
1400	3.25		

For the BIPV, most are installed in the southeast coast, with an average annual effective running time of about 1,200 hours, on-grid price is 3.85 yuan/(kW·h) based on the above-mentioned conditions; for LS-PV desert power plants are mainly installed in the northwest region, with an average annual effective operating time of approximately 1,600 hours, and on-grid price is 2.85 yuan/(kW·h). If with automatic tracking, generating capacity can be increased by 30%, annual operating hours up to 2,000 hours, then the price can go to 2.3 yuan/(kW·h).

In the second half of 2009, solar cell costs fell to 1.5 U.S. dollars/Wp (about 10.5 yuan/Wp), retail price fell to around $ 2.0/Wp (15 Yuan/Wp), then grid-connected PV power generation system investment declined to 20,000 yuan/kW. The Table 23 lists the electricity price calculation under the different initial investment conditions. For the BIPV, to calculate by the eastern part's annual effective running time of 1,200 hours; for the LS-PV, the western part's annual effective running time of 1,500 hours.

It can be seen that, in accordance with the effective operating time (ie. radiation conditions) and financial conditions, when the initial investment of PV system drop to 15,000 yuan/kW (almost the lowest price), the average PV on-grid price will drop to an average of 1.5 yuan/(kW·h). Adding automatic tracking, PV price is expected to reach 1 yuan/(kW·h).

Table 23 Electricity price calculation in the conditions of different initial investment

BIPV(1,200 hours)		LS-PV(1,500 hours)	
Initial investment (1000yuan/kW)	Price (Yuan/kWh)	Initial investment (1000yuan/kW)	Price (Yuan/kWh)
50,000	5.20	50,000	4.15
40,000	4.15	40,000	3.35
35,000	3.70	35,000	2.95
30,000	3.29	30,000	2.40
25,000	2.70	25,000	2.15
20,000	2.20	20,000	1.75
15,000	1.70	15,000	1.38
10,000	1.22	10,000	0.98

(3) Discussion technical line of reducing the cost

At present, the commercial solar cells include crystalline silicon (monocrystalline silicon and polycrystalline silicon), amorphous silicon thin-film solar cells, and other thin-film solar cells (mainly the CdTe and CIGS solar cells), as well as solar concentrators, etc. According to PV News' latest research report (PV Technology, Performance and Cost 2007 Update), the efficiency of various solar cells are likely to have a more substantial increase, and the manufacturing costs are likely to drop to 1 U. S. dollars/Wp in the years between 2012 and 2015.

Based on these projections, by 2012 and 2015, the price of solar cells is expected to reach $ 1.5-2.0/Wp, the initial investment of PV power generation could be reduced to 20-25 thousand yuan/Wp, while electricity prices could drop to 1.5-2.0 yuan/(kW·h). This level is close to commercial standards. In other words, without looking forward to the emergence of other new solar cell, commercialization cost and the corresponding efficiency level can be achieved by improving the existing technology, in order to achieve the scale application of PV power generation.

According to Deutsche Bank's latest forecast, by the year of 2015 or so, the price of solar cells will reach $ 1.0/Wp, the system price of $ 2.0/

Wp, and PV electricity price in the area with good solar energy resources is $ 0.15/(kW · h) (about 1 yuan/kWh). As conventional energy prices rise, by 2015 the price of conventional electricity will reach the same level, PV power generation can achieve "Parity Internet" (Grid Parity), its alternative market will be rapidly expanded, and become the main source of electricity.

3.2.4 PV Incentive Policies in China

3.2.4.1 Renewable Energy Law

The took effect since January 1,2006. China's renewable energy law is basically similar to German's "feed-in-tariff", which means the project developers will charge the initial investment of power generation system, after get administrative permission then to build grid-connected PV generation project. Its cost and profit are recovered through the sale of electricity generated by PV systems, grid companies shall submit full acquisition of PV generation at a reasonable electricity price (cost plus a reasonable profit). For the part beyond the regular on-grid price, the power companies do not subsidize, it will be charged as additional cost and shared by the users in the national grid.

3.2.4.2 Relative Policies

In 2007, State Electricity Regulatory Commission published the 25th order "Full Acquisition of Enterprise Grid Renewable Energy Power Control Methods" (Sept. 1,2007 going into effect), which emphasized that electricity grid enterprises must purchase renewable energy electricity with priority according to renewable energy law and provide grid connection service (cost of power grid connection system is included as additional cost and shared over whole power grid electricity price).

State council published "Energy Saving Power Generation Scheduling Approach" ("measures") jointly formulated by National Development and Reform Commission, State Administration of Environmental Protection, the State Electric Power Supervision Committee and the State Energy Office,

it states under reliable operation, follow energy saving and economical principle, request electricity power grid enterprises schedule renewable energy power, such as wind power, solar PV power.

National Development and Reform Commission published "Temporary Measures of Additional Income Regulation of Renewable Energy Power" in November, 2007. Renewable energy law states the purchase price difference between renewable energy electricity price and regular energy electricity price will be cost-shared in electricity sale price. "Temporary Measures" gives precise definitions and instructions for renewable energy electricity additional income, additional taxation, taxation scope, electricity price additional quota trading and cost sharing plan.

"Price and Cost-sharing Management Pilot Scheme" and "Temporary Measures of Additional Income Regulation of Renewable Energy Power" state: The difference between operation cost of state commissioned or rebated public renewable energy independent electricity generation system and provincial average electricity sale price will be cost shared from renewable energy additional rebate. The surplus of Rebate for renewable energy electricity generation cost reduction can be traded within country.

Since August 2006, state electricity sale price was increased by 0.1 cent to subsidize the renewable energy electricity generation enterprises, added 0.1 cent more in June 2008. Per kilowatt-hour charged 0.2 cent to subsidize the renewable energy electricity generation (including wind power, biomass power generation and PV power generation), about 5 billion RMB may be levied each year. If 2.5 billion/year subsidized to the grid-connected PV generation, 4 yuan per kWh, which can sustain an annual generating capacity of 480MW according to annual generation of 1300kWh per kW; 2 yuan per kWh, then the support of 960MW per year; 1 yuan per kWh, the annual generation capacity of 1.92GW can be sustained.

Renewable energy law has taken effect for three years by now, due to uncertainty of pricing and pricing mechanisms, however, there is still no reasonable on-grid price for PV generation.

3.2.5 China's PV Market Development Issues

3.2.5.1 Renewable Energy Law need to implement urgently

Only to start the domestic photovoltaic market, which can effectively alleviate the adverse effects on PV industry in China caused by the international financial crisis, to promote green energy development in the country, as well as play an important role in sustainable development of our country's energy and the environment. The main obstacle of stagnation in the domestic PV market is the poor implementation of "China's Renewable Energy Law" in PV power generation.

According to "Renewable Energy Law" and "Price and cost-sharing management pilot scheme", as well as "Temporary Measures of Additional Income Regulation of Renewable Energy Power", they are defined incentive policies for renewable energy generation, there are three main principles:

Grid companies must purchase full amount of RE on-grid generation;

Grid companies purchase RE generation at a reasonable price which is consist of the reasonable cost plus a reasonable profit; The part beyond the regular on-grid price will be shared by the users in the national grid;

Wind power and biomass power generation have had a clear pricing and pricing mechanisms, but nothing to PV generation. Therefore, the PV generation market develops slowly. More than 100 grid-connected PV generation projects have been built, but only two projects got on-grid price of 4 yuan/kWh in June, 2008. Photovoltaic power generation's tariff approval procedures and approval process are also unclear.

In 2009, National Development and Reform Commission opened tender for a large desert PV power plant of 10MW in Dunhuang, clearing the price determined by bidding.

For the independent PV generation system and the BIPV, there is no clear mechanism for the principle and subsidy.

3.2.5.2 Industry support system need to improve urgently

(1) Solar Energy Resource Assessment

There are only 17 weather stations that can provide the data of total horizontal radiation and diffuse radiation. In other words, we can only make a scientific forecast of PV generating capacity from these 17 stations, but for most of the other stations, only the amount of solar radiation received by the surface of solar cell matrix can be calculated from the total amount of radiation. And this value is not only related to the horizontal total radiation data, but also to the local latitude, the direct radiation and diffuse radiation components, elevation, sun angle square, the sun square running mode and other factors. Projection is very unscientific, but also imprecise.

The abroad weather stations not only have the radiation data on horizontal, but also the radiation of the South facade, inclined plane and the different tracking planes to the sun. These data will be of great help to photovoltaic and solar thermal power generation design.

China has not yet had the solar resource distribution map under different solar radiation conditions.

(2) Lack of public technical R& D Platform

There are already a variety of domestic solar PV technology R& D units, but the national research funding is limited, so research units could not make substantial progress because of a serious shortage of research funding.

(3) Lack of public test platform

As China's large-scale construction of independent PV power plants and grid-connected PV power station, more and more attention are paid to independent and grid-connected PV system's quantity evaluation and acceptance, on-site detection technology, the evaluation method of new PV generation and other issues. The experiments and test conditions of existing research units and enterprises are lagged far behind, which can't meet the PV product performance testing requirements, also could not guarantee the quality of the PV projects construction.

At present, China doesn't have outdoor PV test lab operations, and is unable to do effective assessment on independent and grid-connected PV power plant, there is also no evaluation methods and tools for many new

technologies in the PV generation field. Therefore, establishing national outdoor PV testing experimental site has an important significance for promoting the development of our independent and grid-connected PV generation system, as well as ensuring project quality and engineering safety of independent and grid-connected PV generation system. State-level outdoor PV testing lab construction will fill gaps of national PV outdoor detection.

(4) Barriers to information exchange and dissemination

There is no institute can acquire PV information free or paid in PV industry. It's urgent to establish a center to provide resources, technology, financing, policy, industry and other aspects of industry-wide information, and provide advisory services for enterprises, schools, government and research units.

(5) No sustainable personnel training system

With the rapid development of PV industry, the corresponding training activities, training institutions and training mechanisms have begun to produce the initial development.

However, with the PV industry will develop with even more rapid momentum in the next 15 years, facing the huge training needs of professional technical and industrial training, college degree training, and even the public dissemination of popular science education and so on, how to build a better, sustainable and replicable training system is an essential important factor.

3.2.5.3 Impact of Financial Crisis

In the second half of 2008, the financial crisis swept the world, and the international PV market declined rapidly. China's photovoltaic industry was tremendous frastrated because 98% of China's solar cell depends on the international market. There are lots of serious unsalable products, many cut-off, semi cut-off, or even closed down manufacturers . The stock of China's several oversea-listed leading PV companies shrunk dramatically, and their funding strand broke, or faced great difficulties.

In addition to the impact of financial crisis, the other reason is the quality which made China's PV module exports dropped significantly. Two years

ago when solar cells are in short supply and silicon material shortages brought big industry profits, some companies used the silicon materials with defects, making some of the Chinese crystalline silicon solar cell performance degradation, some productions have been into the international market, bring a bad reputation and influence. At present, although the international demand is decline, the sales of Japanese Sharp and Kyocera have not been reduced, significantly reduced is the Chinese order. Further reshuffle next year, foreign customers will certainly prefer good quality products, so China's PV companies will experience more severe market test.

3.2.6 Recommendations to Accelerate PV Generation Development

3.2.6.1 Policy Implementation and Management Methods Proposed

"The People's Republic of China Renewable Energy Law" and its supporting policies have been identified incentives and the implementation details of grid-connected and off-grid PV generation, the key lies in the implementation.

(1) Off-grid PV generation and rural electrification

Renewable Energy Law states, for independent off-grid PV power stations, the Government charges the prophase investment, post-operation and maintenance costs exceeded the electricity fee part will be shred as an additional cost nationwide. According to the NDRC/World Bank project study report, the independent PV power plant operation and maintenance costs, the part of which exceeding the tariff revenue are about 5,300 yuan/kW per year (including battery replacement and equipment repair costs, rural energy service companies' technical service fees, taxes and related management costs), which need to implement as soon as possible.

For off-grid residential PV power, although the property belongs to the user, and they will take on all the latter maintenance costs and battery replacement costs themselves, there are still some issues such as big differences in product quality, less maintenance service stations, hard to replace parts. Against to these problems, the proposed management model is as fol-

lows:

• Strict to household solar power compulsory certification system, with particular emphasis on solar household power supply high reliability, easy operation and simple maintenance of properties, to make its reliability and ease lever as common household appliances, such as televisions, washing machines.

• The State provide some funds to help household solar power supplier or local enterprises who are willing to take on after-sale maintenance services for household power to establish solar power supply outlets, at least to the county level, it preferably can be built in the rural area to facilitate the maintenance for common people.

• For the household power supply's after-sale service, to provide paid services in principle, but for especially poor areas, the government can give the appropriate subsidies to the high-value but vulnerable components, such as batteries, through the service stations. And the procedure of subsidy payment should be strict, for example the file must be created, and for each household power supply to provide an allowance for every five years, a maximum of two subsidies.

• To establish training centers in the western provinces, and to add solar power technical training into the national vocational education system for training skilled personnel who are capable of serving in the solar household power supply in remote areas of provincial, county and township levels, but also to help these people to open up Employment path.

(2) Large-scale desert plant

Large-scale grid-connected PV power station in the desert is technically similar to large-scale wind farms, the electricity produced will be routed into the high-voltage grid (10kV, 30kV) from power generation side. It can draw on large-scale wind farm management practices. Moreover DDRC published "Notice of Large-Scale PV Power Station Construction Requirement" and, "Temporary Measures of Additional Income Regulation of Renewable Energy Power", the documents have also identified pricing principles and management methods of large-scale desert PV power station. The prepara-

tion and approval of feasibility study report are basically the same with large-scale wind farms, and on-grid price is determined through a public tender.

(3) Urban grid-connected photovoltaic (BIPV/BAPV)

Urban grid-connected PV generation systems are largely integrated with the buildings (BIPV) or built in the form of building additional (BAPV), usually on-grid at the distribution side (400/230V), electricity issued by the PV system directly is consumed by the load, and the rest dispersed into the power grid. As the light and urban daytime peak overlap, the BIPV can adjust the peak well. The German and Japanese projects of ten thousands of bright roofs, American project of million bright roofs, majority of which belong to the BIPV grid-side power distribution system.

BIPV system is characterized by a decentralized system, with the power from a few kW to several MW range, it is difficult to determine the on-grid price for each project by bidding, and in the management level, it is complicated to compare to large-scale PV power station in desert. Because of worrying about safety and power quality, as well as management of complexity, the Power Grid Corporations do not welcome decentralized BIPV system.

Taking into account the special nature of BIPV, the following recommendations are:

- The Grid Corporation lead to draw up technical standards and management protocols concerning distributed PV generation system of distribution side grid, and to eliminate barriers in the management.
- The Architectural Design Department lead to frame the installation standards and management protocols of BIPV system, eliminating the barriers of construction sector to acceptance PV generation.
- In order to ensure power quality and safety, BIPV systems and all its components should be the implementation of lightweight authentication system, the equipment not certified shall not be used in BIPV, unit has not obtained certification shall not engage in the installation of BIPV.
- On-grid price is not determined by bidding, but through the provincial Development and Reform Commission experts identified the province's fixed PV on-grid price according to the province's sunshine resources, the im-

plementation period of 20 years, while annual 5% decreased price.

- Reporting procedures are implemented in accordance with the file of "Temporary measures of additional income regulation of renewable energy power".

3.2.6.2 Increasing Technology R&D Investment, Enhancing R&D Institution-building

The countries whose PV industry are developed all have national-level photovoltaic technology research institutions, such as the U.S. National Renewable Energy Laboratory (NREL), the German Fraunhofer Institute for Solar Energy Systems, Japan Energy Research Institute and so on. Currently China has no national PV technology research platform. To establish such platform immediately has a very important significance for promoting China's PV industry technological progress.

The platform's main tasks include:

- preparation technology research and development of Solar Silicon Materials.
- Crystalline silicon solar cell industrial technology research and development.
- Solar cell testing technology and testing standards research.
- New type of solar cell research.
- System components and engineering technology research.
- To promote PV technology and information exchange, to provide technical support of relevant decision-making and planning for the State.
- Train PV technical personnel.

The significance and necessity of this platform construction is:

- To build national research institutions of solar cell materials, components and engineering technology, promoting technological progress in the domestic photovoltaic industry through technological innovation and proliferation.
- To build the close cooperation among industry, academy, research units and the government, and speed up the PV industry development.

3.2.6.3 Technical Standards, Management Procedures and Certification System

- In order to power grid-connected PV generation market as soon as possible, the power companies and construction design department must establish corresponding technical standards and management protocols, and eliminate trade management barriers.
- To enhance detection institution building, so that the standards could be implemented consistently.
- To strengthen the building of certification bodies and certification system, so as to regulate the market with the purpose of survival of the fittest.

3.2.6.4 Other Recommendations

- Appropriately adjusting China's PV development strategic planning, to develop science-based PV road map in line with China's national condition.
- To establish personnel training system, setting the major of PV generation in colleges and universities to train research and development personnel on PV cells, related materials, related equipment, as well as the fields of PV systems, and continuously to improve innovative capability.
- Strengthening qualification authentication of PV generation training is an effective way to ensure the training quality.
- Intensifying publicity, as well as raising public awareness, to form the consciousness of loving green energy and supporting environmental protection. This will facilitate the implementation of the national grid price smoothing, and is also conducive to attracting private investment into the PV field.

3.3 Solar Thermal Utilization

Solar thermal utilization mainly includes solar water heater, solar thermal power generation, solar cookers and solar rooms, etc. At present, solar water heater as an economic energy saving and emission reduction product, has formed industrial scale, while the new technology and new prod-

ucts continue to emerge, with varying degrees of development.

3.3.1 Steady and Rapid Development of Solar Water Heater Industry

3.3.1.1 Good Effectiveness of Economy, Energy Saving and Emission Reduction

Solar water heater is an economic, energy saving, emission reduction product in China's water heater industry, it's more economical than electricity & gas water heater, market share improved rapidly, see the Table 24 below. For its energy-saving effect, in the area with I～IV class solar energy resources, per square meter solar water heaters can replace 160kg standard coal a year. Its environmental benefit is obvious in emissions of SO_2, NO_2, greenhouse gases (CO_2) and dust.

Table 24 Market share of three kinds of water heater from 2001 to 2008

Year	Electricity water heater(%)	Gas water heater(%)	Solar water heater(%)
2001	30.00	54.80	15.20
2003	44.23	37.57	22.20
2005	45.20	26.57	28.23
2007	42.30	19.20	38.50
2008	49.2		50.8%

3.3.1.2 Formed a Complete Industrial Chain

China has grasped the independent intellectual property rights of major solar water heaters, and formed a complete industrial chain, as well as a service chain of raw material -solar collector -water heater product industrial chain -sales — marketing. In 2007, annual production of raw materials (3.3 borosilicate glass) was 450 thousand tons, of which only all-glass vacuum coating lines accoumted for more than a thousand, and the annual output of vacuum tube was about 250 million in 2008. Total employment opportunities are more than 2.5 million.

Since 1990, China has been the top listed manufacturer and supplier of solar water heater in the world. The annual production output in 2007 ac-

counted for more than 81% of the world's annual output. But the area of solar collector owned per capita of China are less than that of EU. In 2008, total output reached 31 million m^2. Market sales of 2007 are about 32 billion yuan. There are 2 enterprises with output value more than 1.5 billion yuan, 2 enterprises with the level of 0.5～1 billion yuan, more than 20 enterprises with the level of 100～500 million yuan, The output value of 2008 is 43.0 billion, increased 34.3%. In 2007, the production exported more than 80 countries and export value is more than 65 million U.S. dollars, the annual growth of 28%. In 2008, the exports are 100 million yuan, with an increase of 53.8%.

Table 25 Annual production capacity and possession of solar water heaters from 1998 to 2008

Year	Total output		Increased over the previous year (%)	Possession		Increased over the previous year(%)
	Area 1000m^2	Thermal installed capacity(MW_t·h)		Area (1000m^2)	Thermal installed capacity(MW_t · h)	
1998	350	2,450	——	1,500	10,500	——
1999	500	3,500	43	2,000	14,000	33
2000	640	4,480	28	2,600	18,200	30
2001	820	5,740	28	3,200	22,400	23
2002	1,000	7,000	22	4.000	28,000	25
2003	1,200	8,400	20	5,000	35,000	25
2004	1,350	9,450	12.5	6,200	43,400	24
2005	1,500	10,500	11.1	7,500	52,500	21
2006	1,800	12,600	20	9,000	63,000	20
2007	2,300	16,100	30	10,800	75,600	19.4～20
2008	3,100	21,700	32.5	12,500	87,500	15.70

Universally calculated in the world: 1 m^2 solar collector is equivalent to the thermal installed capacity of 0.7kW.

3.3.1.3 Built and Perfected the Industrial Development Guarantee System

There are 17 original national level standards concerning solar water heater, 3 revised in 2008 and 4 new added. Two national-level product test center were established, which are "National Solar Water Heater Quality Supervision and Inspection Center (Beijing)" and "National Solar Water

Heater Product Quality Supervision and Inspection Center (Wuhan) ." And three solar water heater certification centers were built, China General Certification Center (CGC) --Golden Sun signs; China Academy of Building Research Institute (certification) --CABR signs; and China Environmental United Certification Center Co., Ltd —sign of Shihuan

The first two agencies are carried out on the solar water heater product quality certification, the other agency is to carry out the environmental impact certification of solar water heaters, different focus, but all belong to the voluntary certification.

3.3.1.4 Rapid Development in the Engineering, Rural and International Markets

Engineering market in 2008 accounts for 30%～35% of the total, while the rural market are developing to less developed regions and undeveloped regions, and the international market has expanded to more than 80 countries of five continents, with the rising momentum.

3.3.1.5 Maturing Industry Team

Entrepreneurs: a modern industrial development concepts and strategies, experts in the market and business management; a group of practical experience and a variety of professionals are constantly growing; training a worker team of manufacture and installation service, to develop integrated projects.

3.3.1.6 The Industrial Policy and Preferential Policies are more Clear and Enhancement Gradually

China's solar water heater industry and market developed without incentives. At present, the national or local government published incentive policies to promote the introduction of solar thermal use. Such as "solar water heaters mandatory installation policies of new buildings", and "tax incentives policies on strengthening the solar thermal use technology research and development and promoting industrial development" are introduced in some provinces.

3.3.2 New Technologies and New Products

New technologies and new products of solar thermal utilization are emerging. At present there are mainly the following categories:

- Continued to promote and apply dip compact all-glass vacuum tube solar water heaters, and further improve the product quality and reliability, increase productivity and reduce manufacturing cost;
- To develop and promote technology of low-temperature solar collectors, including efficient collectors, thermal energy storage technology, mechanical and electrical integration, and operating technology, auxiliary energy technology, control technology and building integrated technologies;
- To develop highly efficient flat-panel solar collector technology and industrial production, coating solar absorption ratio of about 0.92, emission ratio with no more than 0.10, glass cover's solar transmittance of about 0.90, the first heat loss coefficient less than 4 $W/m^2 \cdot K$; supporting advanced production equipment of flat-plate collector;
- To develop, produce and promote separated secondary circuit solar water heating systems and other new type of solar water heating systems;
- To develop and promote solar hot water heating technology;
- To develop technology of middle-temperature solar collectors, 80～250 ℃, to broaden solar thermal applications in the industrial and agricultural production: textile, food, chemical industry, refrigeration, air conditioning and seawater desalination, etc.;
- To develop active and passive solar housing technology, air heater, solar cookers and other products;
- To develop solar thermal generation technologies.

3.3.3 Prospect of Solar Thermal Utilization

(1) To Establish Modern Enterprise System and Modern Equipment and to Improve Industry Level

In the 3～5 years, to breed 5 to 10 large-scale backbone enterprises with independent intellectual property rights, brands and international competitiveness, with the annual production of about 2 million m^2 (140MWt · h); To form a number of regional enterprises matching the key to industrial development and suited to accessories specialization; To form a number of integrated engineering companies of solar water heaters and solar collector system.

(2) To Expand and Standardize Three Major Markets

For Solar engineering market, solar energy can be combined with architecture by unified planning, unified designing, unified installation, unified acceptance and unified management. The new buildings meet the criteria for installation should not be restricted to install solar water heaters, and the structural elements of solar water heaters installation should be included when designing new buildings. The rural market should be combined with the new rural construction, and to provide financial subsidies to the less developed rural areas or the socially vulnerable groups. The rural market sales account for about 60% of the total sales in 2010. To actively explore the international market, we should fully improve the product quality and level, and the products should pass through domestic and international testing and certification.

(3) No Less Than 150 million m^2 Solar Collectors in 2010

4 Biomass Energy

4.1 Biomass Resource Status in China

Biomass energy resources refer to a wide range of sources. Based on generated methods and sources, biomass energy resources consist mainly of two categories, one is all kinds of waste biomass produced by industry & agriculture and life, including crop straw, forestry residues, urban & rural and industrial organic waste; the other is the potential biomass resources of artificial propagation, including various types of energy crops, energy forests, etc.

4.1.1 Total Resources

In 2007, the national livestock and poultry manure total amount is 1.84 billion tons, which is expected by 2015 with 2.24 billion tons and by 2020 with 2.54 billion tons. One produced from the large-scale farms accounting for 60% of the total fecal, when 70.3% of the total manure produced from the large-scale farms, 1.58 billion tons; when 75.7% of the total manure produced from the large-scale farms, 1.92 billion tons.

In 2007, the amount of clearing national house refuse reaches 152 million tons, and the actual amount of garbage generated will be more than 150 million tons. Although the concepts and measures of comprehensive utilization of resources and residues reuse will be continuously strengthened in the future, as well the growth rate of garbage generated amount would decline, it is projected that by 2015 the amount of garbage generated will reach 200 million tons/year, and in 2020 will reach 230 million tons.

In 2006, China's rice, wheat, corn, beans, oilseeds, cotton, potato straw these seven major agricultural products' total resources amounts are

about 736 million tons. In addition, a large number of by-products are produced in the primary processing of agricultural product, mainly including rice husk, corncob, bagasse, etc. They mainly come from grain processing plants, food processing plants, sugar mills and wineries and so on, a relatively concentrated place, easy-to-collection and treatment, total amount of more than 100 million tons, equivalent to about 50 million tons of standard coal.

In the past decade, China's grain accounted for 93-95% of the total amount of grain & cotton & vegetable oil, while food production has always maintained between 450～500 million tons. This trend is expected to be a very long time without major changes, so the total amount of straw resources in 2015 and 2020 use the data of 2006.

4.1.2 Available Total Amount Analysis

In 2007 livestock and poultry manure produced by the large-scale farms accounts for 60% of total resources, which can be used as raw material for biogas preparation, 1.103 billion tons. By 2015, manure produced by large-scale farms will account for 70.3% the proportion of national total resources, to 1.58 billion tons; by 2020, the proportion will reach 75.7%, to 1.92 billion tons.

Concerning the house garbage as the resource category that must be dealt with, the amount of house garbage generated can be viewed as the available total amount. Thus, the national available amount of garbage is 152 million tons in 2007, the total available amount will reach 200 million tons by 2015, and in 2020 will reach 230 million tons.

Crop straw is mainly used for returning to field, feed, papermaking, household direct combustion, etc. There are a large number of surplus straw. Based on our field survey result of straw utilization, China's seven major crop stalks of 115 million tons were used to field in 2006, accounting for 15.7% of the total; 122 million tons used to feed, accounting for 16.5%; 227 million tons for household direct combustion, accounting for

30.9%; for industry or other uses is 36 million tons, accounting for 4.9%; and surplus straw is approximately 235 million tons, accounting for 32%. In addition, there are agricultural processing residues of 100 million tons per year, including wheat bran, oil extraction residue treated as raw material for feed production and seed used for oil extraction. There are 36 million tons rice husk served as raw materials of energy utilization every year; peanut shells of three million tons a year; corn cob of 20 million tons every year, in which about 10 million tons used as raw materials to produce furfural, and 10 million tons used as energy. To sum up, the remaining amount of crop straw in China totaled 284 million tons, with straw crops of 235 million tons, agro-processing residue of 49 million tons.

Concerning the total amount and utilization proportion of straw won't change in a long time, the total utilization amount of straw resources in 2015 and 2020 use the data of 2007.

Table 26 below shows the predicted total and available amount of resources in 2015 and 2020, the raw data are the livestock and poultry production, production of grain & cotton & vegetable oil and rubbish removal amount, respectively from "Yearbook of China's Livestock" and "China Statistical Yearbook", the data in the table are the analysis and forecast results of the original data by Energy Research Institute.

Table 26 Forecasting total amount and available capacity of biomass resources (Unit: 100 million tons/year)

Year	Data Type	2007	2015	2020
livestock and poultry manure	Resource total amount	18.4	22.4	25.4
	Available amount	11.3	15.8	19.2
House residues	Resource total amount	1.52	2.00	2.30
	Available amount	1.52	2.00	2.30
Straw	Resource total amount	7.36	7.36	7.36
	Available amount	2.84	2.84	2.84

4.2 Foundation for China's Biomass Energy Industry Development

(1) The implementation of the "Renewable Energy Law" propelled the rapid development of biomass industry

"Renewable Energy Law" was carried out in 2006, and the proportion of renewable energy accounting in the total energy consumption is improved from the current 7% to 15% in 2020.

In the fourth chapter it clearly states the country's energy production companies must fully purchase the electricity produced by the Government's approval renewable energy projects. The renewable energy projects gas and heating enterprises complied with on-grid standards should be on-grid; for renewable liquid fuels in line with national standards, oil marketing companies should include in marketing system. In the 7th chapter, it further provides in the case that the electricity, gas, heat and oil sales enterprises violate this law resulting to economic losses and refused to implement the double penalty. This will have great significance to the development of biomass energy industry, as well as the country's political system progress, market economy proceeding and sustainable development in the future.

(2) The country provides funds to overcome bottlenecks in the development of bio-energy industry

Biomass industry is a new industry based on renewable sources of biomass as raw material to produce energy, bio-materials and other products, also one important way to promote sustainable development. According to China's biomass resources features and technological development status, aiming at the requirements of social development, in 2008 continued to implement biomass projects of special high-tech industrialization approved by NDRC since 2006. According to the requirements of "Notice on the Organization and Implementation of Biomass Projects and Specialized High-tech Industrialization" and "Temporary Measures of National High-tech Industry Development Projects Management" published by NDRC, for biomass spe-

cial projects of high-tech industrialization applied by various relevant departments and provinces, based on organizing the experts to review and advisory body to evaluate, NDRC opened the reporting, examining and approving process of biomass high-tech industrialization demonstration project fund application, and requested the relevant authorities to strengthen management and organization and coordination, speed up project implementation. Strongly supporting a number of biomass industrialization demonstration projects of non-food plant-based bio-energy, bio-materials and bio-raw materials.

The aim of NDRC to implement the specific project is to accelerate the industrialization process of biomass technology development and utilization, to promote the integration and application of biomass industrialization technology development and to provide technical support and application demonstration for the major adjustment of China's energy structure. The special highlights independent innovation and integrated innovation, combined technology development with industrialization, with the core of improving the economics of biomass products and the formation of complete industrial production technology, its main content of the development of biomass raw material, raw material products of industrial processing, an important application of bio-based materials, to promote a new breakthrough in key technologies and products, and to accelerate the formation of China's biomass industry technical foundation and advantage industries.

(3) All levels of government make concerted efforts, the orderly development of biomass energy industry

In 2008 focus on implementing held the spirit of a national work conference on biomass energy development and utilization held in the August of 2006. NDRC, the Ministry of Agriculture, the State Forestry Administration jointly issued a circular text, published meeting minutes and requested that the relevant units to implement them seriously. In 2008, the Ministry of Finance continue to implement the " Interim Measures of Bio-energy and Biochemical Raw Material Base's Subsidies Management," and " Interim Measures of Bio-energy and Bio-chemical Non-food Leading Reward Fund Man-

agement," After the policy carried out, a group of advanced enterprise which use non-grain raw sweet sorghum stalk, sweet potato, and animal and plant oils to produce biodiesel and fuel ethanol, received financial support from the Ministry of Finance.

To implement the "Renewable Energy Law" and the "11th Five-Year Plan of Economic and Social Development", unity thinking, enhance understanding, with a clear mandate and deployment, mobilize all forces to speed up the development and utilization of biomass energy, and in 2008, a marked advance of industrial development.

4.3 Biomass Power Generation

The technology of straw direct combustion power generation is relatively mature either from home or abroad. Its advantages include: enabling large scale development, high efficiency of energy conversion, and avoiding secondary pollution. Meanwhile, utilization of this technology will effectively solve the problem of large quantity of wasted straw in China. It is considered as a method to develop rural economy, increase farmers' income, and optimize the energy structure in rural areas of China. Presently, there are 12 straw direct combustion power plants in China, which all reach the design indicators basically.

Barriers in the straw direct combustion power generation technology are to be removed which include slagging and corrosion, domestic boiler and pretreatment techniques, upgrading of equipments and localization of international technologies. With more biomass power projects being operated, imported technologies and equipments started trying to be fuelled with various types of Chinese biomass, meanwhile, pretreatment equipments and straw boilers with independent intellectual property rights also get demonstrated.

Until 2008, China's grid-scale agricultural and forestry biomass power generation projects are over 25, with a total installed capacity of more than 600 MW, the annual power generation of three billion kwh, consumed vari-

ous types of agriculture and forestry biomass resources of more than 4 million tons. In southern China, Guangdong, Guangxi, Yunnan, it has already formed a certain scale for the sugar industry bagasse used for direct combustion power generation.

4.4 Biogas Industry

4.4.1 Household Biogas in Rural Area

According to Chinese Ministry of Agriculture's statistics, during the period of "10th Five-Year Plan" Government of China totally invested 3.4 billion yuan on the construction of household biogas in rural areas, a total of 3.74 million rural households benefit. In 2008, the state has invested 5 billion yuan to support the building of methane, the national rural household biogas has grown to 30.489 million households by the end of 2008 and the total annual output of methane about 11.388 billion cubic meters, equivalent to about 8.13 million tons of standard coal. Among which, the western region accounting for 46% of the national output; the central region accounting for 45%; and the eastern region accounting for 9%.

4.4.2 Straw Household Biogas Technology

At present, the straw biogas technology has been introduced to more than 100 counties to conduct pilot and demonstration, and achieved good results. Based on the test results and user surveys, for a biogas tank of 8 cubic meters, with 400 kg straw or rice husk, adding 1 kilogram fungus and 15 kg ammonium bicarbonate, the normal gas production can provide a family of 5 people to use over 6 months. The human waste of a family with five members into biogas digester can provide gas production more than 12 months, only 10 yuan per month increased for investment expenditure. However, there are still some strains such as higher prices of bacterial specie, cumbersome management

services of feed-in, discharging, daily management, centralized collection of residue, production of organic fertilizer.

4.4.3 Biogas Project in Breeding Residential and Farm

According to Chinese Ministry of Agriculture statistics, the number of China's large and medium biogas operating projects is 15,910 by the end of 2008, annul 521 million cubic meters of methane, electricity of 60 million KWh, 2.11 million households supplied the biogas, of which 15,625 projects are dealing with agricultural waste, with a total capacity of 3.582 million cubic meters digester, an annual output of 455 million cubic meters.

4.5 Gasification Project

4.5.1 Technology Introduction

Biomass gasification for centralized gas supply system developed into a new biomass energy utilization technologies since 1990s in China. Usually, it takes natural village as a unit. A biomass gasification station provide combustible gas to 10～100 households.

4.5.2 The Promotion of Major Domestic Companies in Recent Years

As the crop straw gasification technology is subjected to resource conditions, the investment scale, gas supply means, transmission distance, economic and many other factors, the straw gasification gas supply system is generally constructed by nature village as unit, with a typical size of 100, 200, 300, 400 and 500 households. In recent years, biomass gasification for centralized gas supply station construction has achieved unprecedented development performance, because of the government sector's strong promotion. Here are a few companies representing the domestic mainstream development of product applications. See Table 27, Fig. 17.

Table 27 Gasification stations development in different years

Year	Shandong Baichuan Tongchuang Energy Sources Co. ,Ltd.	Jiaozuo Straw Gas Equipment Engineering Co. ,Ltd.	Liaoning Beilong Biomass Engineering Co. ,Ltd	Hefei TianYan Green Energy Development Co. ,Ltd.	Total
Before	2	10			12
2000	1	8		2	11
2001	13	2		25	40
2002	18	8		12	38
2003	11	2	2	5	20
2004	13	1	4		18
2005	18	7	6	3	34
2006	29	9	9	17	64
2007	24	6	40	36	106
2008	22	37	18	26	103
Total	151	90	79	82	446

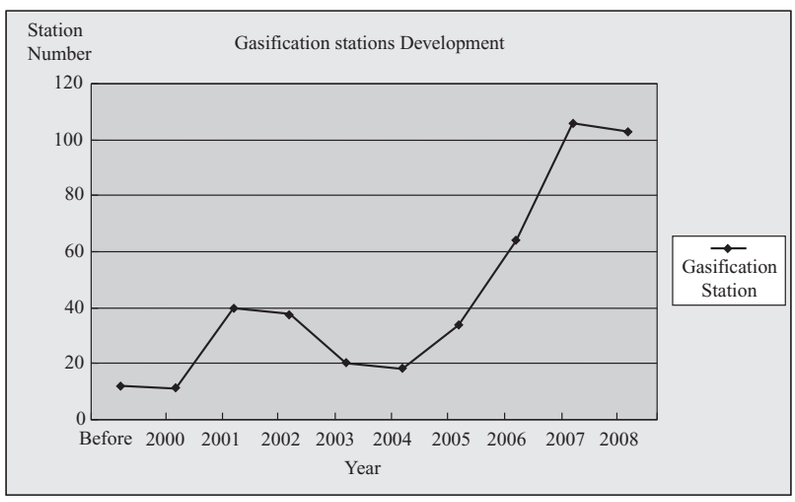


Fig. 17 Gasification stations development status quo

4.5.3 The Development of Main Biomass Gasification Equipment Manufacturing Enterprises

(1) Bio-energy Technology Development Center, Shandong University

This center has long been engaged in research and promotion of biomass technology, a large number of scientific and technological achievements have realized industry promotion and application, also the professional institution of Shandong University in bio-energy technology research and development.

By the end of 2008, the enterprise has promoted biomass technology. in Beijing, Tianjin, Shandong, Shaanxi, Jiangsu, Zhejiang, Liaoning and Heilongjiang with good effect. At present, with biomass gasification equipment, Shandong University has consistently ranked No. 1 in the national market share for three years, has built biomass gasification gas (heating) projects, large and medium sized biogas projects, straw gas -methane gas joint works more than 100 items, covering the northeast, north, east and north-west region.

(2) Liaoning Beilong BLJQ-300～600 type straw gasification unit

BLJQ-300 ～ 600 type straw gasification unit produced by Liaoning Beilong Company, has run 3 years since the first set of equipment ran at the beginning of 2004. During the past three years, the company has built more than 30 straw gasification stations in Liaoning, Inner Mongolia, Hebei and Xinjiang, more than 40 sets of straw gasification unit installed and in normal operation until now. By detection of tar $<10mg/Nm^3$; gas calorific value $> 4,650kJ/Nm^3$ (up to 5800 kJ/Nm^3); oxygen content $<1\%$; carbon monoxide content $< 20\%$, a number of indicators are better than the NY/T443—2001 standard. Complemented by good service and standardized management, the Shenyang municipal government has repeatedly increased to support it in the past two years. After the inspected by Zhang Xingxiang secretary accompanied with the Central Research Room, Shenyang government included the straw gasification as "New Countryside" four changes project into the "Eleventh Five-year" Plan.

(3) Hefei Tianyan TY series biomass gasification gas supply system

Hefei Tianyan Green Energy Development Co., Ltd. is a professional high-tech company engaged in green energy development and product research. Since its inception, the company has been committed to green energy project design and construction, and the products reach over 50% of the do-

mestic and international market share, as well exported to Japan, Italy, Thailand, Malaysia, Indonesia, United Kingdom and other countries.

The TY series of biomass gasification equipment for centralized gas supply primarily use fixed-bed negative pressure suction operation, with air as gasification agent, in the big gas volume, the continuous work occasions, use of circulating fluidized-bed gasification equipment. Since the first demonstration project of straw gasification for centralized gas supply was built in 1998, 82 projects already in the domestic construction.

(4) Energy Research Institute of Liaoning Province FGAS series biomass gasification for centralized gas supply system

The technology of this system comes from China -Italy international scientific and technological co-operation results and the State "85", "95" science and technology research project results. The gasifier is downdraft fixed bed, with the feature of high-temperature pipe, uniform air distribution systems, both high-temperature pipe and a grate. The packed-type cyclone is improved on the base of the cut-flow cyclone, setting the padding to enhance dust removal efficiency. Spray cleaner uses atomization to trap impurities, according to different occasions, using downstream type or counterflow. The heat exchanger design is to cool the spray water. While spray washing, the clean cooling water flows in the outer loop, and cools down as well spraying water and gasification gas. Filter using granular bed filter technology for horizontal single-layer. Different granularity levels of sawdust and planer chip are used as the fillings of filter, and can be removed regularly into the gasifier for gasification, replaced with new filter.

(5) Jiaozuo Straw Gas Equipment Engineering Co. , Ltd.

Founded in 1998, the company is specialized in biomass energy and biogas energy technology development in rural area, development and installation of special equipment, steel gas-storage cabinet manufacture, the laying of pipeline network, installation of household gas facilities, civil engineering design of dry distillation carbonization plant, operator training and quality after-sales service. The company insists technology innovation, quality oriented, safety first and good faith, with the Ministry of Agriculture Rural

and Renewable Energy Key Laboratory (Henan Agricultural University), Henan University of Chemistry and Chemical Systems as the technical support units.

It's the only authorized producing company of "Straw Gasification Unit" in Henan Province, has constructed and installed 37 demonstration projects of straw gasification for centralized gas supply inside and outside the province for several years. After a long run in practice, it is proved that the company's product with good quality, safe and reliable operation, stable gas supply, advanced and mature technology, both economical and practical, Praise is well received from customers and industry experts, all projects passed the projects acceptance organized by the Science and Technology Office. By the end of 2008, totally 90 biomass gasification stations have been built.

(6) Henan Fucheng Eco-Energy Technology Co., Ltd.

Henan Fucheng Eco-Energy Technology Co., Ltd. formerly known as Jiaozuo Yongan Chemical Equipment Manufacturing Co., Ltd., is established in 2000, and it develops into a high-tech enterprise after the re-oriented with Shenyang Fucheng Eco-Energy Technology Co., Ltd. development in accordance with the Group mode.

The company established the joint-stock operating mechanism, improved the standardized management system, perfected quality assurance system and after-sales service system, and fully passed the ISO9001: 2000 Quality Management System Certification. It is the "High-tech Enterprise" of Henan Province, "Winning Unit" of the Ministry of Agriculture straw gasification tender project, the technical support unit for "JRQ-II-type Straw Gasification Unit" recognized by the Ministry of Science and Technology, also the implementation unit of "2002 National Promotion Program Focus on Scientific and Technological Achievements" and the "2004 National Key New Product Plan" projects, one of the national "SME Technology Innovation Fund Grant Funded" enterprises. The honors achieved are 8 State-authorized patents, 6 "Certificate of Scientific and Technological Achievements in Henan Province", 3 "High-tech Products in Henan Province",

one "National Key New Product" . And has won the provincial and municipal government issued "Scientific and Technological Progress Award" six times.

Since its establishment, the company has implemented 56 projects of straw gasification for centralized gas supply in Henan, Shanxi, Hubei, and Chongqing and other provinces and cities.

5 Geothermal Energy

5.1 Feature of National Geothermal Resources

Geothermal resource includes geothermal energy, geothermal fluid and other useful components which can be exploited and utilized economically. Geothermal resource is a very important kind of renewable minerals and clean energy, and can be inexhaustible in supply and always available for use with rational development and utilization. Geothermal resources can be used in healthcare, tourism and chemical industry as well.

Geothermal resources have conduction and convection types. According to the temperature, it can be divided into 3 grades as high-temperature ($T \geqslant 150℃$), medial-temperature ($90℃ \leqslant T < 150℃$) and low-temperature ($T < 90℃$). Shallow geothermal energy within a range of depth under the surface of ground is also a part of geothermal resources.

5.2 Geothermal Resource Assessment

Scientific investigation and assessment of geothermal resources is the foundation of its planning and rational development. The investigation mainly includes analysis of regional geological materials, remote sensing imagery interpretation, investigation on geothermal geology, Geochemistry and Geophysics, geothermal drilling and dynamic monitoring. Since national founding, the geothermal and geological work has been developed in all aspects and there's basic conclusion of national geothermal resources circumstances.

At present, geothermal resource assessment can refer to the national standard The Regulations for Geothermal Resource Investigation GB11615—89. The resources calculation focus on geothermal energy in geothermal reservoir and geo-

thermal fluid, meanwhile calculate energy in geothermal reservoir (J), amount of geothermal fluid storage (m^3), exploitable amount of geothermal fluid(m^3/d or m^3/a), and its containing thermal energy (J). The temperature limitation of spring vent (wellhead) in mountain area is 25℃, place's temperature lower than that is not going to be evaluated. The area where the geothermal gradient is over 3℃/100m in plat area carries on geothermal resources calculation in unusual area. Calculate the amount of geothermal resources and geothermal water in the area whose depth smaller than 2000m. According to this standard, it is estimated that storage geothermal energy of the main sedimentary basins in our country is 73.61×10^{20}J, equal to the heat produced by 250 billion tce. The exploitable hot water is 6.8 billion m^3 per year, containing thermal energy of 963×10^{15}J, equivalent to the heat productivity of 32.84 million tce every year. And exploitable amount of geothermal water in mountain area is 1.9 billion m^3 per year, thermal energy is 335×10^{15}J/a, equivalent to the heat productivity of 21.42 million tce per year. Exploitable water of geothermal water in mountain and plat area separately account for 28% and 72% of total amount and exploitable thermal energy in mountain and plat area separately amount to 35% and 65% of the total exploitable amount in China.

Because currently there is no assessment criterion for the total quantity of shallow geothermal energy, geothermal resource buried deeply more than 2000m and the resource in the geothermal gradient non-unusual area haven't been evaluated. In conclusion, the estimation is limited instead of all the geothermal resources. The total quantity is still indefinite, the methods of calculation and evaluation are imperfect, so the further researches on national geothermal resource is necessary to make a more actual overall evaluation.

5.3 Exploitation and Utilization of Geothermal

China has a long history in developing and utilizing geothermal energy. Recent geothermal resources development began from 1950s. The main-

ly utilizations of geothermal heating are on the aspects of medical bathing, aquaculture, industrial washing and so on. In the 1980s, the development had reached a fast growing phase. Especially since 1990, market economy demands have promoted the flourishing development of geothermal energy, getting the maximum depth above 4,000m. Up to now, the geothermal exploitations emerge in every province (autonomous region, directly governed city region) and have been used widely.

According to the statistics, with the direct utilization of geothermal energy resources reached 12,604.6GW·h and installed capacity was 3,687 MWt by 2005, ranking first and third respectively and the growth can be 10% per year.

At present, the main utilization of geothermal resources in China is producing electricity and direct utilization.

5.3.1 High-temperature Geothermal Power Generation

The national high-temperature geothermal resources mainly distribute in southern of Tibet, western of Yunnan, western of Sichuan and Taiwan. Himalayas geothermal zone is the biggest and most concentrate area of china mainland geothermal resources, especially the high-temperature geothermal potential electricity area, with the potential electricity capacity of 2,781MW; almost high-temperature geothermal potential electricity capacity is about 3, 036MW in total. The Tibet area of Himalayas geothermal zone has the most powerful potential electricity.

About 1970s, some small capacity of geothermal testing power machine sets have been built in Fengshun Guangdong, Huailai Hebei, Yichun Jiangxi, Huitang Hunan, Zhaoyuan Shandong, Yingkou Liaoning and Xiangzhou Guangxi. But most of the testing stations stopped due to low temperature and very limited economic benefits. At end of 1970s, China began to produce electricity using high-temperature geothermal resource and built industrial geothermal power stations in Yangbajing and Langjiu of Tibet in succession, reaching total installed capacity of 28.18MW. Among them

there was 25.18MW installed capacity for Yangbajing station. Combined with water vapor (1.095×107m^3 flow、temperature 130～170℃) the actual power generation was stabilized on 18.5MW which accounted for 40% of annual electrical supply from power grid in Lasa and exceeded 60% in winter. To sum up, China geothermal power has a total installed capacity for 32.08MW up to the present, of which 88% of installation is located in Tibet, the installed capacity accounts for 0.35 percent of the world's total, ranking the 14th (World Geothermal Conference, 2005).

Table 28 List of China geothermal power station (station) **installed capacity and operation situation**

Station name	Unit No.	Unit Capacity /MW	The year for run	Total capacity /MW	Operation situation	Notes
Yangbajing Tibet	1 2 3 4 5 6 7 8 9	1 3 3 3 3.18 3 3 3 3	1977-10 1981-11 1982-11 1984-04 1986-03 1987-02 1988-02 1990-12 1991-02	25.18	1982 stopped running running running running running running running running running	thermal power unit conversion D3-1.7/0.5 produced by Qingdao Jieneng motive power Group except No1 and 5
Naqu Tibet	1	1	1993-11	1	2000 stopped running	"ORMAT" duplex circulatory
Langjiu Tibet	1 2	1 1	1987-10	2	Stopped running	Unit conversion
Fengshun Guangdong	3	0.3	1984-04	0.3	2006 stopped running	Decompression expansion
Huitang Hunan	1	0.3	1975-10	0.3	running	Decompression expansion
Qingshui Taiwan	1	3	1981-09	3	1995 stopped running	
Tuchang Taiwan	1	0.3	1985	0.3	Stopped running	"ORMAT" duplex circulatory

Typical high-temperature geothermal power generation project---The Yangbajing geothermal power station

(1) Overview

Yangbajing is the first scaled-up power station using wet-steam and high-temperature geothermal fluid technology in our country. There're eight 3MW units working alternately and well, with total operation time about 4,500-6,000 hours. Since 1993, the electricity capacity was stabilized on 0.1 billion kWh per year, which accounted for 40% of annual electrical supply from power grid in Lasa before 1996. Now joining in mid-Tibet and account for about 10% (Jiao Xingyi, etc, 2007). Table 28 is the description of annual electricity capacity from 1977 to 2008.

(2) Key technology

- In order to improve the efficiency of geothermal fluid and enhance the output of electricity power generation, we adopt two-stage broaden-capacity geothermal steamy power generation system;
- Relieve the corrosion of facilities by using resistant materials and spay coating;
- Adopting hollow heavy hammer and the chemical way to prevent and clean stains to insure the normal output of wellhead;
- Through own technology of power station, make in use of speed control system, reform hollow system and improve the safe stability of units' operation;
- Accomplish the third-phase recirculation project, let parts of waste water recycle.

(3) Comprehensive utilization

- Build a 50 thousand m^2 geothermal green house by using waste water come from electricity producing, which can produce about 5,000 kg vegetable per mu every year;
- Develop geothermal tourism, build spring tourist resort and an open-air spring swimming pool at plateau with a altitude near 4, 300 meters;
- Develop aquaculture by using cycled water and build a 15.000m^2 fishpond with hot water.

(4) Development of deep-level geothermal resources

Going through 30 years, Yangbajing power station mainly develop the shallow storage energy of geothermal fields. In order to insure stable and sustained operation, the power station has investigated deeper resources of geothermal fields in particular sulfur deposit and thermal groove in the north with related departments since 1988. From 1988 to 2004, there're 5 deep well created with the highest temperature of 329.8℃, indicating the great potential in electricity producing. The deep geothermal fluid from ZK4001 well was connected into Yangbajing's Second Factory to generate in 2004.

(5) Total power generation produced in Yangbajing geothermal power station

At present, the power generation of Yangbajing power station account for about 10% of mid-Tibet grid. Total energy is 2.26, 704 billion kW·h from 1977 to 2008 (Jiao Xingyi, 2009).

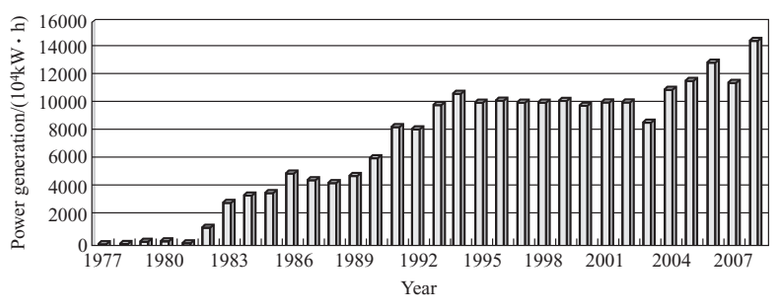


Fig. 18 The generated eletricity energy of Yangbajing geothermal power station in Tibet, by the end of 2008

(6) Power generation test with new screw expansion motor in Yangbajing

The 1MW screw expansion motor (model: SEPG 500-500/2400-2S) invested by Long Yuan Company that belongs to State Power Corporation was installed at ZK4001 well of Yangbajing Second Factory and began to test. It's made up by 2 sets of 500kW front-type screw expansion motor units.

The test run has been taken many times without the expected result, and experts are still working on it.

The principle of screw expansion motor is retrorse application of screw compression, put the low-medium-temperature geothermal fluid that going through

filter device into screw expansion motor with some stress, then power generation using screw expansion motor. This kind of technology is applying low-medium-temperature geothermal fluid to generate. Our country has produced 500～1,500 kW units. If the screw expansion motor units test finally successful, it'll promote the development of power generation using low-medium-temperature geothermal resources, which are abundant in China.

(7) Future development

The energy stored in shallow of Yangbajing, under development for 30 years, has a reduction in storage gradually. The power station make a decision to develop deeper high-temperature geothermal recourses in north geothermal fields to replace current shallow resources with the purpose of making the station operated stably and constantly. Plan till 2, 035, a 12MW unit changed to serve deeper high-temperature geothermal fluid resources and another 12MW unit still serve the former shallow fluid resources. And total installed capacity remains 24MW. (See Fig. 19)

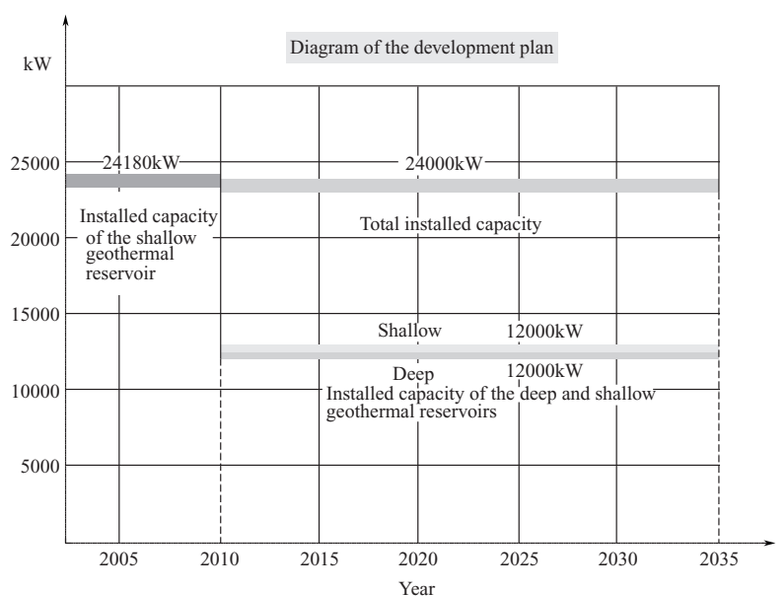


Fig. 19 Diagram of the development medium and long-term plan of Yangbajing geothermal power station (Jiao Xingyi, etc, 2007)

5.3.2 Direct Utilization of Low-medium Temperature Geothermal Energy

In China, the direct utilization of low-medium temperature geothermal resource mainly focus on geothermal heating, medical care, bathing, tourism, aquaculture, greenhouse planting, irrigation, industrial production and production of mineral water. And the technologies for step-recycling and energy storage in the aquifers are developed gradually. At present, among the application methods heating supply make up 18%, both of medical care and entertaining body-building account for 65.2%, aquaculture get 9.1% and others is 7.7%.

(1) Geothermal heating The application form large-medium cities, such as Beijing, Tianjin, Xian, Zhengzhou, Anshang in North and some oil regions including Daqing of Hei Longjiang, Bazhou of Heibei, Guan, Nutuozheng and so on where low-medium temperature geothermal water, tailrace and shallow geothermal energy with 60-100℃ are exploited. In the North, use geothermal heating in different degree getting a good effect. The statistic data show that in 1990, the area of national geothermal heating have 1.9 million m^2, and reached 11 million m^2 in 2000, up to now, it have approached 20 million m^2 together with the area of ground source heat pump (See Table 29).

For instance, North China Petroleum Administration Bureau have built heating demonstration projects by using deoiling hot water heating at many place, dealing with the problem of local heating in oil field and saving millions yuan per year from fuel and power. Taking full use of waste oil well and exploiting and utilizing geothermal resource are a developing direction of economic restructuring of oil field.

Table 29 Situation of geothermal heating

Category	1990	1999	2005
Area of geothermal heating(10^4 m^2)	190	800	1,270
Domestic hot water by geothermal energy(10^4 m^2)	1	20	30
Carbon emission reductions(ton)	3,087	12,999	20,635
Nitrogen dioxide emission reductions(ton)	1,158.65	4,878.5	7,744.6

(2) Medical treatment and health care Geothermal fluids have high temperature, special chemical constituents and gas composition, a few biological activity ion, radio material and so on. It helps to treat every system and organ in body for medical care. There are all kinds of hydrotherapy, gas therapy and mud therapy conducted by geothermal energy in hot spring sanatorium. A bath of Hot spring Villages or Medical Rehabilitation Centers eme rge successively with medical treatment, bathing, health care, entertainment, tourism vacation in our country. The data show that there are 126 geothermal fields for medical care in our country, distributed in 20 provinces (districts, or cities).

(3) Bathing and tourism vacation The distribution of this geothermal bathing has been wide-spread almost through all over China. According to incomplete statistics, there are 200 hot spring sanatoriums and 430 bath therapies which focus on medical care. Except sanatorium, in the exploited geothermal fields, geothermal area used fully or partly in bathing reach over 60% of total geothermal field, with both of hot spring public baths and pools of 1, 600. It is estimated that in nationwide scope geothermal water used in bathing is about 138 million m^3 every year, with using geothermal energy of 716.45 MW, equaling to saving or reducing the standard coal consumption of 771,000 ton, or offering geothermal bathing for 400 million person times.

China has lots of spring areas which are both sanitaria and tourist resort, and also were sportful places only for royal family. For example, there's a Pond special for Empress Dowager in Xiaotangshan Beijing, Hall of Glorious Purity Hua Qing Palace in Lintong Shanxi, Pond and Ba Gua House built for Empress Wu Zetian's own use in Linru spring in Henan and so on. Along with the development of tourism, spring recuperate industry develops speedy especially, many investigation have been taken in spring areas on the aspect of geothermal utilization and more and more places for spring and tourism created owing to this.

Not only boiling spring area have geothermal resource of high energy sites, but also have beautiful geothermal landscape attracting attention of

common people. For example, Tengchong of Yunnan province is the only well-preserved volcanic hot spring area with rare volcanic, geothermal sight and rare medical mineral water. Hot spring area in Datun of Taiwan also is hot spring recuperate and sightseeing tourist attractions.

(4) Aquatics Breed, first starting from Beijing, Tianjin, Fujian, Guangdong etc. Now there are 47 geothermal fields, 300 aquatics farms, rearing pond area of 445×10^4 m^2 distributed in 20 provinces (including special district or city). Nation-wide water consumption of aquaculture make up about 5.7% of total quantity of geothermal water, mainly cultivating tilapia, etc., turtle, bullfrog, fancy fishes etc. and fry over wintering. Moreover geothermal hatching avian, geothermal drying vegetable, heating biogas digester by geothermal water and bathing pool for livestock also get a good result.

(5) Agricultures greenhouse planting and irrigation Making use of geothermal resources is very adaptive for out-of-season growth of plants and allopatric aquaculture. Geothermal energy can be used to supply heating for greenhouse and geothermal water can be used for aquaculture in warm zone, at the same time, mineral composition can offer necessary nutrient for living creature. In the north of China, the geothermal energy are mainly utilized for planting slap-up melon and fruit、greengrocery, domestic fungus, flowers, and mainly utilized for seeding culture in the south of China. The Data show that there are 1.33 million m^2 area used for geothermal greenhouse in our country. Utilization of geothermal water on agricultural cultivation and irrigation not only promote early maturity but also make obvious effect on yield. Up to now, in our country exploitable geothermal energy for greenhouse planting standard coal goes to 215,000 ton/a, accounting for 3.4% of annual produced quantity of geothermal resource.

(6) In Industrial production, geothermal energy is mainly used for textile dyeing and printing, washing dyeing, tanning, pulp wood and grain heat-drying, while some industrial material is extracted from part of geothermal water, as getting the sulfur by elutriation method in Rehai area, excavating mirabilite and native sulfur in Jiutai hot spring area of Eryuan. North China Oil field conducted the oil transportation accompanied

with geothermal water by using ordovician arranged in deep part of well, taking place of oil transportation accompanied with boiler hot water to get economic and social benefits.

There're brands such as "The Village of Spring in China" and "The City of Geothermal Energy in China" created in Guangdong, Xianyang, etc. Thus improving overall standard of geothermal resources' development and utilization in areas and accelerate regional economic development. Meanwhile the stair-type utilization of geothermal water makes apparent progress in economy and has been spread all over the country.

5.4 The Problem in Exploration and Development of Geothermal Resource

(1) The insufficiency of resource assessment. Investment is insufficiency, and most regions haven't conducted exploration of geothermal resource yet, especially low-medium geothermal resource in west of China. Though some areas have been investigated, are not suitable to meet the development's need due to limited technical and economic standard. About 103 geothermal fields are endorsed by Resource Storage Management Department for further exploration and development, accounting for 1/3 of discovered geothermal fields. The exploration and evaluation lag behind the exploitation and utilization, the work on exploration of fundamental geothermal geology was weak and lack of support resources, planning on exploration, resource using and development of geothermal industry are influenced greatly thereby. Work such as evaluation and demonstration on the planning and exploitation and evaluation of regional geothermal field resource for government at different level are lagging and government administration department can't live up to scientific management.

(2) Developing and utilizing technology on geothermal resource at low level and serious waste of energy resources. At the same time, the extent of scale and industrialization wasn't ideal. Natural hot spring water wasn't take full advantage in a certain extent; recovery ratio of geothermal resource produced from well was low, and the utilization method was sole, which lead to

high temperature and wasting water too much. Especially in some organization using direct offering and direct discharge, the utilization ratio of heat energy was just 20%～30%, which seriously waste the geothermal resource.

(3) Geothermal wells were centralized too much in some region. Excess exploiting without supplement caused the continue decreasing of geothermal water level and land subsidence in part of region, making bad efforts on sustainable utilization of geothermal resource seriously.

(4) High-temperature geothermal energy developed slowly in these 20 years, no additional installed capacity attached. Using dry-hot rock resources to generate electricity is still blank in relevant field of our country. Whereas the technology develops well overseas and we need to investigate and research geothermal resources urgently to offer fundamental materials for our country's electricity industry applying geothermal resources.

(5) The technology of geothermal pump make shallow geothermal resources very useful and not only for heating but also for cooling. However, the utilization of heat pump in our country is still at an initial stage. It is of great practical significance and has promising prospect for vigorous development of shallow geothermal energy. Country should guide and support positive development and utilization of shallow geothermal energy by enterprises, units and individual from the aspects of policy and funding.

5.5 The Problem on the Development and Utilization of Shallow Geothermal Energy

5.5.1 The shallow geothermal technologies of heat pump system

In China, the start of shallow geothermal energy was a bit late, the shallow geothermal technologies of heat pump system wasn't promoted and researched until 1990s. Since 2000, popularizes widely in our country, especially Beijing and Tianjin.

Through shallow formation, the off-season storage that means supplying heat of geothermal source for constructions and recharging cooling

source to formation, and then cooling source would be offered to building in summer, exchanging the heat source again will be conducted. Nowadays China has improved the engineering technologies, mechanical equipments, and system of monitoring and controlling, but the recharging technology is still unknown.

Engineering technology on shallow geothermal energy is classified to ground source heat pump system, groundwater source heat pump system and surface water source heat pump system based on cold and heat source engineering. The low-temperature heat stored in soil and water can be well used by applying geothermal technologies of heat pump system. It also can be used for saving heating from low-temperature used geothermal water, reducing the discharge temperature of used geothermal water and increasing using temperature difference of geothermal energy.

5.5.2 Current situation of shallow geothermal energy's development

Available shallow geothermal resources spread widely in china. Using them in a scientific way makes contribution to building conservation-oriented society, energy conservation, emission reduction and developing circular economy. In recent ten years, with the support and initiative of government, some big cities began to exploit shallow geothermal resources one after another, and developed relevant technologies at a quick pace, particularly in Beijing and Shenyang. In recent five years, Beijing has already built more than 500 projects applying shallow geothermal energy, heating area beyond 10 million m^2; the area of shallow geothermal resources application has reached 18 million m^2; Beijing achieved the goal of conservation and emission reduction in 2006, utilization and exploitation of shallow geothermal resources made great contribution. Application on shallow geothermal technology became highlight of Beijing Olympic Games in 2008 and Shanghai Expo in 2010. Beijing is working on establishing assessment and plan of shallow geothermal resources in Beijing plain area, which can be set as a model to promote all round the country. At present, there're 31 provinces, municipalities and autonomous regions have projects of shallow geothermal resources utilization and exploitation. And related governments make some pol-

icies and regional rules to promote. For instance, government offers allowance for projects applying shallow geothermal resources in Beijing; all of buildings should use shallow geothermal technology if possible in Shenyang; there're foundation set special for renewable energy in Chengdu, Chongqing and Ningbo, which in use of developing shallow geothermal resources, offering concessions for loan and policy to related and high-tech companies.

5.5.3 Problem and prospect

There're some problem appeared in the project of heat pump system of shallow geothermal energy utilization. For example, heat pump project or underground heat exchange system couldn't work or have a low efficiency, etc. In these cases, we should distinguish whether it's pure technical problem or problem caused by irregular design, construction and operation respectively. Some places had not taken any investigation and developed without making any scientific plans, are lack of knowledge of environmental assessment and control of research on hydrothermal balance of constructed programme, that's the basic reasons leading to the above problems.

Investigation of shallow geothermal energy include: investigation of areas and sites. Assessment of shallow geothermal energy is a complete process that every link should be connected perfectly. On the foundation of outdoor investigation and experiments, first find suitable areas for ground source heat pump system and groundwater source heat pump system; then calculate power of exchange heat, obtained heat in heating period and discharged heat in cooling period, capacity of shallow geothermal of each areas; then carry on assessment of underground heat-balance using above results. It can adopt figure simulation to forecast the long and dynamic changes of underground temperature, estimate whether geothermal energy can be balanced or not, demonstrate the insurance of obtained heat in heating period and discharged heat in cooling period so that the environmental assessment of shallow geothermal energy development can be taken. Value the amount of recycled water of underground water and surface water heat exchange system, meanwhile satisfy the demonstration of water resource of constructed program. Only through investigated way can make use and protect the necessary

geologic materials of shallow geothermal resources, reduce risk of development, make the biggest benefit of both economy and environment sides and make sure the resources become sustainable.

According to the prediction, utilization of shallow geothermal energy will be developed rapidly recently. By the year 2020, there will be 100 million m^2 areas using shallow geothermal energy to make warm and cool, the heating power will reach 5,000MW.

5.6 Long-medium-term Strategy of Geothermal Resources Development

Based on resource assessment, the exploitation and development of China geothermal resource may be component of the national eleventh five-year energy planning.

In connection with features of geothermal resources, make united manage rules among the whole country and complete the manage regime. Make preferential policies to encourage the development of shallow geothermal and to promote experiment on the exploitation of hot dry rock resources.

Carry on a new term of investigation and demonstration of national geothermal resources. In particular make factual assessment on shallow geothermal resources, convection-type geothermal resources in mountain areas, conduct geothermal resources in basin and deep hot dry rock resources, offering support for plans and utilization.

Strengthening research and extension on technologies of geothermal energy, and promoting the utilization and recharging technique of shallow geothermal energy and. Using heat pump technology, shallow geothermal energy is developed for heating and cooling, with good economic and environmental benefits. It is worth to be promoted. For protecting geothermal resource and environment and changing the situation of consumptive exploitation, geothermal recharging technique must be the key measures. People should strength study on geothermal water recharging in different geological conditions and encourage application.

To develop technology of hot dry rock utilization (power generation) and enhance the scale of high-temperature geothermal energy, our government should make incentive policy to use geothermal energy power generation just like what it did to other renewable program. Insisting the principle of "from easy to hard", from "shallow to deep", from "offering heat to generating electricity" and "from experimenting to promoting", we should develop the technology of hdr-hot dry rock utilization as soon as possible, so that geothermal energy can develop at a stride.

Set up a batch of demonstration areas of geothermal development and utilization. For sustainable development of geothermal resource, some examples of development and utilization aiming at one aspect should be set in different type areas. The experimental units mainly focus on shallow geothermal energy heat pump technology, geothermal water recharging, geothermal concentration heating, geothermal cascade utilization, exploiting geothermal energy through oil field wells, high-efficiency agriculture and so on, which can boost sustainable utilization and efficient development of geothermal resource.

In accordance with the total capacity of exploration is 350 million and the average water temperature is 50℃ (make use of 35℃), the available heat energy is about 1,800MW, of the directly utilization of geothermal energy (spring). Respectively calculate as annual growth rate is 10%, 5%, 3% of 2020,2030,2050.

6 Ocean Energy

6.1 Classification and Definition of Ocean Energy

Ocean renewable energy consists of tidal energy, wave energy, ocean/tidal current energy, ocean thermal energy and salinity energy, among which tidal energy and tidal current energy derive from the moon and the sun's gravitational force, while other ocean energies originate directly or indirectly from solar radiation.

6.1.1 Tidal Energy and Tidal Current Energy

The gravitational attraction (is vector sum of centrifugal force, inertia force, and gravitation between moon and sun) generated during the process of relative motion among earth, moon and sun, lead to periodic change of sea levels-the tidal phenomenon. Generally, water level changes in vertical direction and it's called tide, the regular seawater flow caused by tide called tide current. The energy carried by the movement of seawater fluctuating is divided into two parts: the energy carried by vertical movement is potential energy, e. g. tidal energy; the energy carried by seawater's flow is kinetic energy, e. g. tidal current energy. Tide energy between tidal prism and tidal range (the difference between highest and lowest water level in one cycle) is direct proportion.

Besides, tidal energy can be used in water storage and new land.

6.1.2 Wave Energy

Wave energy refers to the kinetic and potential energy reserved in the sea waves. It is a kind of mechanical energy, which is generated by wind and stores in short-period waves with the form of kinetic and potential ener-

gy. Wave energy is in direct proportional to the square of wave height, wave movement period, as well as the width of opposite wave face. Wave energy is the most volatile energy. It is mainly used for power generation, and can also be used for transportation and pumping water, heating, desalination of seawater and producing hydrogen.

6.1.3 Ocean Current Energy

The gradient of density and pressure of seawater caused by asymmetrical distribution of seawater temperature and salinity, or windward upon sea surface and so on, these reasons lead to basically stable flow of seawater, called ocean current. The kinetic energy carried in ocean current is ocean current energy. Compared to wave energy, ocean current energy is more stable and regular. In general, there is practical value for ocean current energy development if the largest flow rate is above 2m/s along the channel.

Likewise tidal current energy, its energy between square of velocity and flow is direct proportion. It has similar principle with wind power generation. Tidal current energy is the prime in china, therefore ocean current energy ranged in.

6.1.4 Ocean Thermal Energy

The most quantity of heat radiated by sun are taken in by surface seawater and radial circulation of ocean that conveying heat and so on, lead to the phenomenon that sea surface (by the sides of equator) temperature is relatively high and deep water is cold. As there is temperature difference between surface seawater and deep seawater in low-latitude area, there exists thermal energy, whose size is directly proportional to the quantity of heat water in area that has enough temperature difference (generally no less than 18℃) and temperature difference.

Ocean thermal energy used for power generation, meanwhile deep seawater can be used for aquaculture and open cycle can desalt seawater.

6.1.5 Ocean Salinity Gradient Energy

In the area along river bank or sea coast, the chemical potential difference between seawater and freshwater, or seawater with different salt concentration (concentration difference of solution) carries a kind of energy-ocean salinity gradient energy. There're many expression of ocean salinity gradient energy, the most attractive is a potential energy showed by osmotic pressure. So called osmotic pressure, is that fresh water will go to seawater through semi-permeable membrane (only allow solvent to pass) when putting one between two kind of solution with different concentration, the water level of one side will keep on rising because of additional water and this process won't end until the difference in height reach h, which is called osmotic pressure. How big the osmotic pressure is decided by concentration difference. Size of ocean salinity gradient energy is directly proportional to the quantity of fresh water and osmotic pressure.

6.2 Development of China's Ocean Energy Resources

The first ocean energy resource investigation was started in 1958 in China, the second census on coastal tidal resources was finished in 1985 and regionalization of coastal ocean energy resources in rural area accomplished in 1989. Coastal salinity gradient energy and maritime, adjacent water wave energy and ocean thermal energy resources have not been investigated formally, with only several scholars' research.

6.2.1 Tidal Energy

According to the statistic of *census on coastal tidal energy resources in China* and *regionalization of coastal ocean energy resources in rural area in China* to the 426 dam sites that available installed capacity over 200kW, the national coastal tidal energy resources that can be developed has total installed capacity as high as 2.179×10^7kW, with an annual generation ca-

pacity of 6.24 × 10^8 kW • h. The resource is accounted for up to 80% in Fujian and Zhejiang provinces, then only 5% in Guangdong province and 4% in Liaoning province, other areas are even less.

Zhejiang and Fujian have done lots of investigation, design planning and feasibility research on the sites of coastal tide power station. There're 10^4 kilowatt class medium tide power station that obtain development condition in Jiantiao port of Sanmen Zhejiang, Huangdun port of Ninghai, Bachimen of Fuding Fujian, Daguanban of Lianjiang and Maluan gulf of Xiamen recently.

6.2.2 Wave Energy

Using the wave materials observed by 55 ocean stations for one year as representation and refer to regionalization of coastal ocean energy resources in rural area in China, the average power of national coastal wave energy resources is 1.2843×10^4 MW. Taiwan province holds a maximum of China's total coastal wave power, about 33% of the national total wave energy. It is followed by Zhejiang, Guangdong, Fujian and Shandong, about 55% of the national total. Other coastal provinces and cities possess a relatively small portion.

The Bohai Sea straits (Beihuang city), north and south side of Taiwan Island (south Taiwan and from Cape Fugui to Cape Sandiao), mid Zhejiang (Dachen Island) and to the north of Haitan Island in Fujian (Beishuang and Tai Mountain), Xisha area and Yuedong (Zhelang), etc. have relatively high wave energy density in the coastal areas of china.

6.2.3 Tidal Current Energy

According to statistical calculations of *regionalization of coastal ocean energy resources in rural area in China* from 130 costal channels, the theory average power reached 1.395 × 10^4 MW. Zhejiang province holds a half of national total ocean current energy, which is maximum. It is followed by Taiwan, Fujian, Shandong, Liaoning provinces, accounting for about

41.9% of the national total ocean current energy. The rest provinces have less.

In nationwide coastal water channels, north of Hangzhou gulf, Jintang channel in Zhoushan Islands area, Guishan channel, Xihoumen channel, Laotieshan channel of north of the Bohai Sea Straits, northwest of Sanduao and Sandujiao of Fujian and southwest of Yuweng island of Penghu Islands area in Taiwan have superior tidal current energy resources.

6.2.4 Ocean Thermal Energy

According to the calculation of mainland scholars and estimation of power company in Taiwan province, the available installed capacity of ocean thermal energy resources of maritime and adjacent waters in china is about 1.840×10^{6}MW, of which 90% distribute in South Seas.

The north side of South Seas 10cates China mainland and Taiwan province, the south side of Daxunta Islands, while Philippine Islands stand in the east and Zhongnan Peninsula and Peninsular Malaysia in west part. Both the east and west sides of waters are channels and connected the Pacific Ocean and Indian Ocean, and also a semi-enclosed epeiric sea. South seas has the highest of energy density and most ample resources among maritime and adjacent waters in China.

The benthic topography of the eastern area to the Taiwan Island are intensely declining from east shore of Taiwan to the Pacific Ocean and greatly changed in maritime depth of water. The area whose depth reach 1,000m is really close to the shore and there're lots cliff on the shore which it's very benefit for exploitation so that is a good place to build plant going on development.

6.2.5 Ocean Salinity Gradient Energy

According to statistics, China's average flow rate per year of all the coastal rivers is about $(1.7\sim1.8)\times10^{12}m^{3}$, it has been calculated that the corespondingly theoretical power of China's total salinity gradient energy is

about 1.14×10^8kW. Opening area of the Yangtze River, the Pearl River and the Minjiang River to sea, the flow quantity is very huge and salinity gradient energy changes slightly, meanwhile there are quite developed cities so that become ideal places for future development of ocean salinity gradient energy.

6.3 Ocean Energy Industry of China

6.3.1 Tidal Energy Industry

By the end of 2008, there're only three tidal power stations still in work, which are Jiangxia, Haishan and Baishakou tidal power station, while all the others have been torn down or out of running.

Jiangxia test tidal power station is the biggest tidal power station of our country currently. It's located in Jiangxia port in southwestern Wenling of Zhejiang, 16 kilometers from the city. Jiangxia test tidal power station belongs to China Guodian Corporation as Pic. 3 shows and is in charge of subsidiary company-Longyuan power group corporation.

6.3.1.1 The Jiangxia Test Tidal Power Station in Zhejiang Province

Now the total installed capacity of station is 3,900kW and power generation ability reaches 7 million kW·h per year. Not only much power energy but also lots of benefit from aquaculture or tourism obtained after the power station's establishment. The reservoir created because of dam and is able to

Pic. 1 The Jiangxia test tidal power station

Pic. 2 Reservoir of the station

store water for 1.37 square kilometers, also can be used to develop aquaculture. The affection of nature environment is very small, lots of nutrition contained in water owing to fresh water so that the salinity of seawater reduce, therefore Aquatic Products always harvest. According to incompletely statistics, reservoir can make over 15 million yuan/year.

Pic. 3 Plant of the station

Pic. 4 Facilities of the station

During the process of construction and production, many scientific experiments task have been finished. All of these experiments demonstrate that there's no need to immigrate, no disposable of energy consume, no threaten of flood, no pollution and no harm to the eco-system of tidal power station. There're 76 people work in the station and more than 30 people retired. Considering both company's benefit and cost of running, the price of on-grid electricity in Zhejiang is 2.58 yuan/(kW·h).

The expansion project of the No. 6 unit of Wenling Jiangxia test tidal power station, is to attach a new two-way (rising and falling tide) 700kW lie-axle-bulb through-flow power unit to No. 6 using the former hole and channel. Compared with five former units, the forward and reverse operation conditions of pump are additional and thereby enhance function. After No. 6 unit's expansion, the station installed capacity increase from 3,200kW to 3,900kW. The plan and design work are in the charge of Hangzhou Machinery Design Institute belongs to the Water Resources Ministry and the task are classified in the national "863" Plan. The project started on Jan. 7th, 2007 and finished on Oct. 18th the same year. In addition, the project won the first prize of Advance of Science and Technology Award of China Guodian Corporation in June, 2008.

6.3.1.2 The Haishan Tidal Power Station in Zhejiang Province

The installed capacity of Zhejiang Haishan tidal power station is 2×125kW and the water turbine made by turbine production in Hengchuan Henan, design to generate power 400 thousand per year. It'll be enlarged to 3×250kW, planned by local government in 2008. The area of station's reservoir reaches 418 mu, seawall dam is more than 2,000m in height. It's the first double reservoirs, one-way and full-tide small tidal power station that store fresh water and energy for power generation, meanwhile develop aquaculture using reservoir. It's a key program of "sixth-five" of Science & Technology Commission in Zhejiang.

Pic. 5 The Haishan test tidal power station

Pic. 6 Reservoir of the station

Pic. 7 Tail water gate of the station

Pic. 8 Unit of the station

Haishan tidal power station renamed to "Zhejiang Yuhuan Double-current Tidal Power Ltd." in May of 2008, is attached to Yuhuan Water Resources Corporation. There're five staff now, working on operation, maintenance, management of the tidal power station and aquaculture. The price of on-grid electricity is 0.46 yuan/(kW·h), among which the cost of power generation is 0.63 yuan/(kW·h). It's obvious that the station's running

can't rely on selling electricity but the income of aquaculture.

6. 3. 1. 3 The Baishakou Tidal Power Station in Rushan Shandong

Shandong Haiyang Suoyin Shoal, a natural bay that absorb water when tide is rising and drain water conversely. Its waters area is four square kilometers, coastline is 12 kilometers in length and water is two meters in depth. It's the biggest natural and inland tidal lake in china so far.

Pic. 9 The Baishakou tidal power station (Epigraph by Chen Yun)

Pic. 10 Plant of the station

Pic. 11 Reservoir and dam of the station

Pic. 12 Facilities of the station

The design installed capacity of Baishakou tidal power station is 6 × 160kW and its generator is made by Chongqing Electrical Machinery Factory, the speeder is produced by Hangzhou Gear Factory, the units assembled by themselves and can generate power like 4,000kW•h a day on average. By the end of July 2008, the tidal power station has made power of 38. 20 million kW•h in total. The area of reservoir reached 32 thousand square kilometers when the station established. But the area is getting smaller and smaller due to the development of tourism and real estate that the reservoir is filled in partly. There're six units in

the factory at the beginning, but No. 5 and No. 6 unit have out of running because of serious corrosion.

There're seven people working in Baishakou tidal power station, taking charge of the operation, maintenance and management of the tidal power station and aquaculture. But the price of on-grid electricity is only 0. 32 yuan/(kW · h), the power generation can't support the station along, benefit from aquaculture contributes to.

Table 30 list the status of electrical energy of the above three tidal power stations.

Table 30 China tidal power station (station) **operation situation in 2008**

Station name	Installed Capacity(kW)	On-grid Price (yuan)	Electrical Energy (10^4 kW · h)	Operation Unit (set)
Jiangxia	3,900	2. 58	720	6(6)
Haishan	250	0. 46	27	2(2)
Baishakou	960	0. 32	100	4(6)

6. 3. 2 Wave Energy Industry

Wave energy device has been formed only a kind of good i. e. beacon lamp 10W oscillating water column (OWC) device. The device is specially designed for pharos buoy in the sea-route by the Chinese Academy of Sciences Guangzhou Institute of Energy Conversion. According to the recent application on the sea, the device will make the navigation lights illuminate bright and stable, greatly improve the navigation conditions.

Pic. 13 10W beacon lamp

Since this device takes wave as the driving force and gets electricity locally for navigation light, it will no longer need to replace the battery, saving maintenance costs, and reducing labor intensity of navigation workers. It has ob-

vious economic and social benefits. This devise is designed and manufactured by Guangzhou Energy conversion Institute. And 2008 annual output is 10 units, one of which exported to Japan.

6.4 China's Ocean Energy Research

6.4.1 2008 Events

Since 2008, considering the serious situation that increasing scarcity of conventional energy sources, country gradually began to pay attention to renewable energy, particularly ocean energy resources, scientific research and industrial status quo. National Science and Technology initiated projects on ocean energy development and the key issues of projects, carrying out all kinds of scientific and research about various Energy Type of ocean.

In mid-February 2008, the Chinese Academy of Engineering set up a "China's energy and long-term(2030,2050) development strategy consulting project team research," conducting a comprehensive investigation and study about renewable energy in China including ocean energy, and putting forward long-term development plan of China's ocean energy.

In March 27, 2008, the China Renewable Energy Association Professional Committee of Ocean Energy has been established. Representatives from national universities, research institutes such as the State Oceanic Administration Ⅰ, Ⅱ, Ⅲ, Institute of Chinese Academy of Sciences Guangzhou Institute of Energy, East China Exploration and Design Institute, Harbin Engineering University, Dalian University of Technology, Zhejiang University, Shanghai Jiaotong University, China Ocean University, Huazhong University of Technology, North China Electric Power University and Jiangxia Power Station, Haishang Power Station, Happiness Power Stations, which are ocean marine energy industries, and other units, a total of 70 people, attended the meeting.

And in May 10, 2008, the Ministry of Science and Technology issued "Key Technology Research and Demonstration of Ocean Energy Develop-

ment and Utilization" application guide of key projects topics supported by national science and technology program. National science and technology program funds allocated 32 million Yuan in total. From May 2008 to April 2011, a program, aiming at China's power shortages in remote islands of the status quo, focusing on China's ocean energy key technologies of development and utilization, was carried out to establish relevant procedures and detection methods, and overcome the key technologies of our wave energy, tidal energy, ocean thermal energy, make on-site demonstration test and improve our independent innovation capability of ocean energy development and utilization, lay the industrial development foundation of China's marine renewable energy exploitation and utilization. The key supported projects are follows:

- The key technology research and demonstration of 100 kW floating wave energy power station.
- The key technology research and demonstration of 100 kW Swing wave energy power station.
- The key technology research and demonstration of 20 kW ocean/tidal currents energy device.
- The key technology research and demonstration of 150kW tidal energy power station.
- 15 kW Ocean Thermal Energy power generation equipment research and testing.
- Ocean energy generation systems Integrated Test study.

May 20, 2008, 863 plan in the field of advanced energy technologies, issued renewable energy technologies topics, and plan to allocate 600 to 700 million Yuan in 3 years, to support the new technologies of the ocean energy utilization. The Ministry of Science and Technology demands each R&D to focus on the current, look forward to the future, and vigorously develop energy-saving, development of clean and efficient energy, and conversion and utilization technologies, and actively develop new energy technologies, promote energy diversification; capture a number of energy development, utilization and energy-saving key technology and equipment, form a number

of new growth point for the energy industry, and establish energy technology sustainable innovation platform, to support economic and social sustainable development in the provision of clean and efficient energy technologies. Research directions supported by 863 plans are as follows:

- MW-class tidal power engineering optimum design selection.
- Key technologies of analysis and location of resources.
- Various operating mode simulation technologies about tidal power.
- The efficient ocean power generation conversion technologies.
- New technologies of ocean energy application.

6.4.2 Research project

6.4.2.1 Wave Energy

Guangzhou Institute of Energy in 2008 won the project approval of the ministry of Science and Technology project. Ministry of Science and invested 13.4 million to support the four projects:

- Floating wave ocean energy independent stable power generation system (863 Exploration Project).
- Application technology of floating direct drive wave energy (863 Exploration Project).
- 100kW floating wave energy power station (the project sub-topics supported by science & technology).
- 100kW off-bank stationary and swinging wave energy plant (the project sub-topics supported by science & technology).

The goals of these projects and issues are to complete a canard-10kW floating wave energy device in 2009 and a 10kW direct drive oscillating float floating wave energy device in 2010, and a floating canard 100kW wave energy power station in 2011, as well as 100kW fixed offshore wave energy power station.

In October 2008, the floating wave energy device with efficiently anti-typhoon ability got through the initial destructive testing, in December 2008, and it completed a preliminary test on real sea conditions.

In addition, there are other units involved in wave energy research, including the State Oceanic Administration, Tianjin Marine Technology Center, South China University of Technology, China Ocean University and so on.

6.4.2.2 Ocean/Tidal Current Energy

Because china's tidal current energy is greater than ocean current energy, the primary research and development experiments are about tidal current energy equipment.

(1) A 1kW underwater floating horizontal-axis tidal current device, which is developed by Northeast Normal University.

It is consist of underwater mooring system, generator, flexible shaft and horizontal-axis hydraulic turbine. A high efficiency hydraulic turbine was employed. In order to avoid paddle-distance adjustment and decline of the efficiency at reversed flow condition, this device used flexible shaft, which connected the horizontal axis hydraulic turbine and the vertical-placed generator, making sure the hydraulic turbine faced against the flow direction. The research was supported by MOST 863 exploration projects of "11th Five-Year Plan". It began in November, 2006 and will be completed in December, 2008.

(2) A 250kW surface floating vertical-axis tidal current device, which is developed by Harbin Engineering University and Italian Archimede Bridge Company. This device employed ship-type carrier and Italian Kobold vertical-axis hydraulic turbine. The project was supported by MOST 863 directional projects of "11th Five-Year Plan" and UNIDO (United Nations Industrial Development Organization). It started in August 2007 and is expected to be completed in December 2009.

(3) A 5kW fixed type horizontal-axis tidal current device, which is developed by Zhejiang University. This device employed a stationary base to fix the hydraulic turbine. The project was supported by MOST 863 exploration projects of "11th Five-Year Plan". It began in August 2007 and is expected to be completed in December 2009.

6.5 Suggestions on Ocean Energy Development

Considering the application of technology and development, the countries adjacent to the sea based on their geographical location, focusing on different study of ocean energy development and utilization, at the same time, ocean energy in the country's energy reserves have a large proportion, showing that the country pays much attention on the oceans energy.

Given the recent progress in ocean energy research and industry, as well as the support of national policy, ocean energy study and exploitation is imperative. Based on existing ocean energy research and industrial bases, we could find that China's ocean energy development and utilization have following characteristics:

(1) The development and utilization of ocean energy in China has been a foundation to some extent. China has built the most tidal power station in the world, such as Jiang Xia, Haishang and other power stations, accumulated equipment manufacturing, operation and grid-tied power generation experience, and laid a solid foundation for the exploitation and utilization of ocean energy.

(2) Ocean energy development project can be comprehensive utilized. Existing installations, which are included in the plan when it was introduced, including other use, besides power generation, such as aquaculture, beach land reclamation, desalination, coastal tourism and so on.

(3) Our existing ocean energy exploitation technologies have always been consistent with foreign countries, rather than lagging behind with foreign advanced level. In the area of existing tidal energy and wave energy device, china has independent intellectual property rights of technology and equipment.

(4) Ocean energy exploitations and utilizations are capital-intensive high-tech projects, marine works have inherent risks, and need large initial investment, as well as need to be support by national policy, and also need systematic exploitations, which have different focus.

The future direction and way of ocean energy should focus on addressing some problems about unpowered small-scale facilities on the sea (including

offshore buoys, Xisha, Nansha islands or reefs on the military and civilian, etc.), such as electricity and water, as well as realization of regional electricity supply and commercial installations, which should be the long goals, to conduct relevant research and experimentation. On this basis, it is recommended to carry out the following aspects of the content, recently.

(1) To complete the ocean energy regional functionalization, including verification and verification of offshore ocean energy resources data survey and near-shore data.

(2) To build comprehensive utilization of ocean energy test site (test site is built by the government and enterprises together), determining the exploitation position in the ocean zoning, to build test site, including pre-assessment research, equipment construction, materials research, marine engineering construction.

(3) Develop the design and manufacturing technology of low-cost ocean energy utilization device, in order to form the industrialized developmental basic device.

For tidal current energy, we should expand based on the existing power station, to meet regional power levels, and actively develop new station sites, completing 2～3 10MW-class power station construction.

For wave energy, we should develop 10 kW-class small wave energy device, in order to be able to supply offshore installations power, and provide energy for the desalination of sea water. On that basis, research and develop 100 kilowatts-class small-megawatt wave energy devices, or megawatt-class large-scale wave energy device.

For tidal current energy, we should conduct MW-class experimental power station construction and grid-tied power generation.

For the ocean thermal energy, we should do thorough research on low-pressure steam turbine and low-boiling-point working medium turbine, undersea long pipeline, efficient heat-exchanger with large capacity and energy conversion system, finish the preliminary tests on the sea hereby offering basic data for the construction of power station.

For salinity gradient energy, we should, based on discussing the feasibility, complete the theory and feasibility study.

7 Analysis and Prospect

7.1 Problems Faced by Renewable Energy Development

RE development achieved gratifying results, but the majority of RE technologies in China is still in the transition stage from research and development to the industrial production. The crisis and problem faced by China's RE technologies large-scale and orderly development exists in the resource assessment, technology research and development, reasonable pricing, intervention and regulation of power grid, market discipline and so on.

7.1.1 RE Development Goal Formulation is not Scientific

7.1.1.1 Analysis of the RE Development Target Already Set Down

In September 2007, Government of China officially released the Medium and Long Term Planning for Renewable Energy Development, including renewable energy objectives, summarized in Table 31.

Table 31 Summary of RE power generation target (GW)

Year	2005	2010	2020
Hydropower	117	190	300
Biomass Power	2	5.5	30
Wind Power	1.26	10	30
Solar PV	0.07	0.3	1.8

Objectives for other renewable energy sources are: non-food bio-liquid fuel, in 2010: 2 million tons fuel ethanol, bio-diesel of 200,000 tons; in 2020: 10 million tons fuel ethanol, bio-diesel of 2 million tons.

Solar thermal utilization: in 2010, a total collector area of solar water heaters will reach 150 million square meters, together with other solar ener-

gy heat utilization, the annual amount of alternative energy sources to reach 30 million tons of standard coal; in 2020: the total collector area of solar water heaters is about 300 million square meters, together with other solar energy heat utilization, the annual amount of alternative energy sources to reach 60 million tons of standard coal.

Compared the goals developed with the actual RE development situation, as well as the analysis of existent problems, the national RE development goal-setting is lack of scientificalness, and need to be adjusted. Overall, without regarding to grid constraints, installed capacity of wind power could reach 80 million kilowatts to 100 million kilowatts by 2020, or even 150 million kilowatts, far over originally planned goal of 30 million kilowatts; For solar water heater, it's entirely possible to achieve the original goal or exceeding the original target; solar PV power generation will also have a huge development. However, the bio-liquid fuels and biomass power generation will be very difficult to achieve the original goal, even not achieve.

The development of bio-liquid fuel is considerably uncertain because of the immature second-generation bio-fuel technologies, under the national "non-food" strategy. There is a big contradiction between the biomass power generation objectives and resource availability amount, if estimated by the current technology level, 1.8～2 million tons of straw will be consumed to achieve the goal of 30 million kilowatts installed capacity, and according to recent estimated available amount of straw, totally less than 2 million tons, so the biomass power generation target needs to be reduced.

7.1.1.2 Key Issues Affecting the Scientific Establishment of RE Development Goals

From 2008, as well as the RE development situation after renewable energy law enacted, it's very difficult to achieve the desired national middle-long-term goals of RE development due to a variety of reasons, in particular, some renewable energy technologies are not mature. See the overall analysis, there are two main factors affect the scientific establishment of RE development goals:

(1) The weakness of basic technology research and development, tech-

nological immaturity and high cost, it's difficult to judge the future application level and scale. Compared with fossil energy, the cost of RE technology development and application remains high. Including wind power, renewable energy sources with high cost, but mostly intermittent, the government policy support is strongly needed to do large-scale development and utilization of renewable energy sources. Such as biomass energy, especially bio-liquid fuel technology and cost trends are not clear, for example, cellulosic ethanol system, although with the great potential application, but the technical immaturity. Therefore, technology and cost is one of the main bottlenecks which effect renewable energy development and scale application.

(2) The level and intensity of resource assessment is far less than the project demand. If China's RE resources can be implemented in specific development project or the development goals implemented to specific project, the intensity of resource assessment will be found not enough: First of all, the development potential of wind and solar energy is the largest, but resource assessment is too general and simple. Secondly, the bio-energy utilization projects built in the past few years have been facing serious supply problems of resources, the uncertain biomass resources is the main reason. For example, land resources, in particular non-cultivated land resources that can be used for the cultivation of energy crops is unclear; water resources corresponds to the available land resources is unclear; for the available plant and biological species resources, no evaluation of their economy, drought tolerance, etc; eco-environmental resources is even more fragile, and require in-depth evaluation. Thirdly, resource assessment on geothermal, ocean energy has not yet really started.

7.1.2 Haven't Formed the Pricing Mechanism Conducive to the RE Development

China has not formed a rational pricing mechanism for RE power generation. For wind electricity price, there are a variety of forming methods, and the price has a great difference in projects with the similar resources, also because of intense competition, including solar energy power generation,

renewable energy project has experienced a number of bids at unreasonable prices, affecting the health of the industry sustainable development.

Article 19 of Renewable Energy Law states: The on-grid price of RE power generation projects will be decided by the State Council department according to different types of RE power generation characteristics and circumstances in different regions, according to the principle conducive to promote RE development and utilization and economic rationality, and timely adjustment is also needed based on RE development of technology development and utilization. On-grid price should be publicized. In fact, after a few years implementation, what is the principle conducive to promote RE development and utilization and economic rationality, it is a vague concept, that is "conducive" and "economic rationality" cannot be scientific explained in price-making process, RE power generation pricing mechanism hasn't been formed, which adapt to China's national conditions and resources status.

7.1.3 The Power Grid has become a Constraining Bottleneck for RE Development

At present, China has formed six regional power grids: north, east, northeast, central, northwest and south, but the six major power grids are relatively independent, Xinjiang is out of Northwest and western Inner Mongolia is relatively independent to North China, the entire power grid can't support 1 mutually like Continental Europe and the United States, and even Russian synchronized power grid, shown in Fig. 20 and Fig. 21. Although the national total installed capacity of power generation is very large, close to 800 million kilowatts (by the end of 2008), in particular the installed capacity of thermal power accounts for 80%, can effectively support the intermittent RE electricity, mainly referring to wind power and PV power generation, but the actual situation is not the case, the key issue is that our power grid are not synchronized, but the relatively independent regional power grid.

China's RE rich resource regions are mainly in the west, north and northeast, while the power load in the central, eastern and southern,

Fig. 20 Six regional power grids

Fig. 22 shows the peak load of the national leading power grids in 2007, RE power must be transferred from the rich resource regions to the central and southeastern regions with high power load. Wind power and PV power is highly intermittent electricity, no single region can afford 10 million kilowatts, as well as the future's RE electricity of 100 million kilowatts. Whether the six national power grids can support each other to achieve simultaneous connections will be the biggest bottleneck for China's large-scale RE electricity development.

7.1.4 Lack of the Mechanism of Industrial Training System and Personnel Training

At present, the technology development has lagged behind the industry development needs, mainly reflected in: Enterprise lack of core technologies, industrial development lack of sustained national inputs. The result is

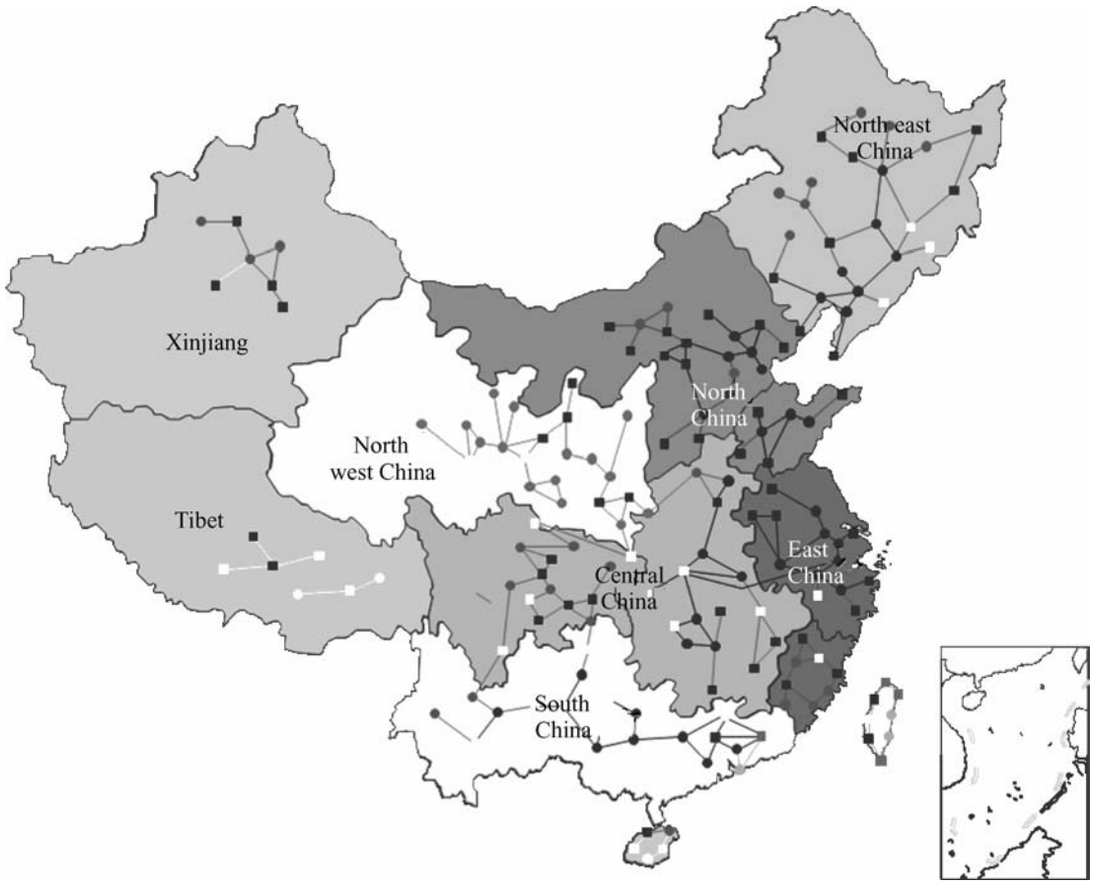


Fig. 21 Current status of the relatively independent power grid

industrial development has lagged behind market demand, expressed as: RE industry are mostly new business, also many speculative enterprises, it is precisely lack of strategic investors' participation, sustainability of the industry development is worrisome.

The mechanisms of industry training and personnel training are inadequate mainly in the following areas:

(1) RE products, technologies, standards and testing certification system have not been fully established. Although China's RE industry have made great progress, and all kinds of RE products' production capacity has significantly improved, there still hasn't established a complete equipment and the standard system of key components, as well no national standards of the matched electricity access, liquid and solid fuels, lack of standards also

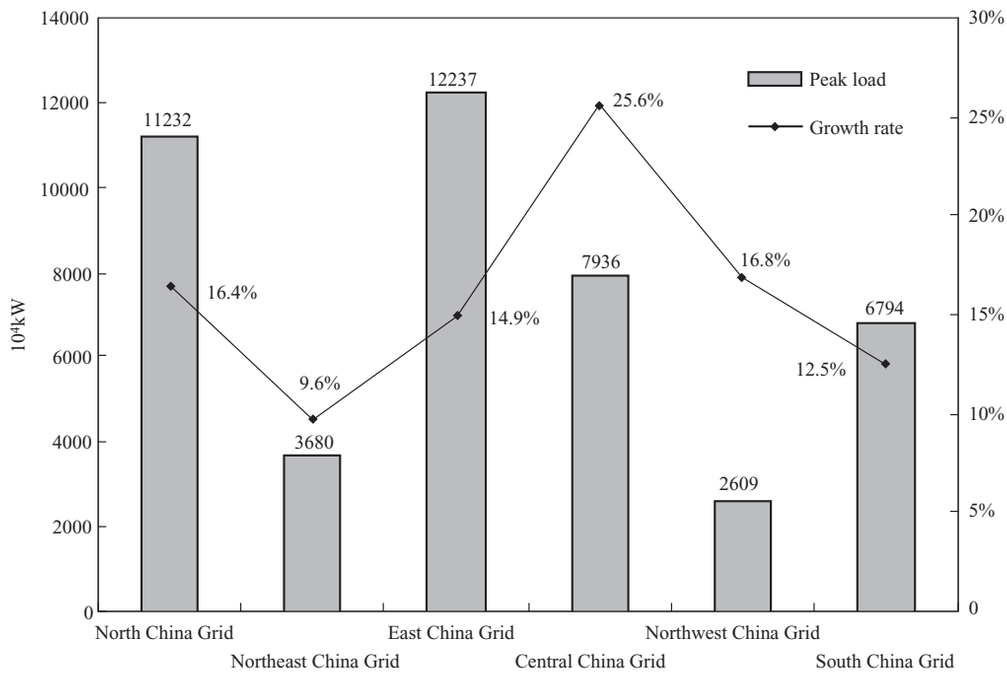


Fig. 22 The peak load status of the national major power grid in 2007

affected the establishment of corresponding testing, certification system, accordingly negatively impacting the sustainable development of industry.

(2) The lack of effective, independent regulatory capacity and the evaluation mechanism of legal implementation effect. From the national and local levels of NDRC or Economic and Trade Commission's organizational structure and staffing situation, its main function of energy management is planning and manning quotas, industry guidance, investment licensing and price supervision, they have no administrative capacity to supervise and manage the RE development and utilization activities, in accordance with law (including information collection, administrative inspections and penalties, etc.); SERC is limited to the electricity market regulation, the functions are too narrow and cannot do the effective supervision and management of the whole complex RE system from resources development, processing and marketing. The lack of regulatory capacity will lead to some problems in the industry, which cannot reflect timely and appropriately, for example: the

low bid of wind power, good condition rate of wind power equipment, wind power rationing, as well as too hot industrial development in certain areas and other issues, there is no normal channels to reflect as well as no capacity to respond.

(3) Consciousness is still lagging behind, inadequate capacity-building. For the RE development, there still need two diametrically opposed attitude: the negative, it's insignificant and dispensable; the positive, it's so significant that need to develop rapidly. Different development consciousness and attitudes will affect the country's policy support oriented. In fact, China's conventional energy sources are generally equipped with state-level energy technology research and development and industrial services, for example, coal with Research Institute, Planning Institute; Electric Power with Research Institute, Planning Institute, Petroleum with Research Institute, Planning Institute of Engineering; hydropower with Research Institute, Planning Institute; Nuclear Energy Technology Research Institute, etc., there are still a large number of professional design institutes on electricity, coal and oil, also many national-level research institutes, the university also has a strong research forces, all of these formed a more complete public service system of conventional energy sources. Most of these institutions were set up in early China, providing a strong technical support to China's energy technological progress, industrial development and engineering building, played an important role in the development of conventional energy sources in China. However, China did not set up research institutions and specialized engineering and technical management bodies for renewable energy, a small amount of technical strength dependent on conventional energy sector, there is still blank in many areas of RE industry. Compared with conventional energy sources, China's renewable energy professional and technical force is scattered and difficult to create a support system for technological innovation, no management entities for national RE policy, planning and priorities, which is not conducive to independent technology innovation capability and industrial systems improved. If this trend continues, China won't own a complete RE industry system and national strategy targets for the RE development are difficult to achieve.

7.2 Suggestions to Promote Renewable Energy Development

7.2.1 To Formulate the RE Development Goals Scientifically

Goal is to successfully source, too high or too low is infeasible. How to scientifically formulate goals for RE development is the key to China's large-scale RE development. There are mainly two aspect basic work to do for China's RE development: First, the State provide the fund to do dialed survey and evaluation of wind resources, solar energy resources, biomass resources, lay the foundation for the layout of wind, solar and biomass energy development projects; Second is to accomplish different types of RE technology development road map. Only know resources well, understand the technology and industry trends, a practical RE development plan and objectives can be worked out.

7.2.2 Set up the RE Price Mechanism According to the Resources Pricing

To improve the RE power generation project management and price management system, forming a rational pricing mechanism. To further improve the formation of RE tariff and cost-sharing mechanism. For different RE power generation technology features, industrialization process, resources, in order to achieve China's RE goals, to promote the healthy development of industry, to encourage technological progress, and to lower the cost, a reasonable price formation and the cost-sharing mechanism should be formulated, such as wind power price by the resource pricing, solar power using the fixed price with the annual reduction on the basis of tender and so on.

7.2.3 To Establish National RE Development Fund

Renewable energy industry is a new energy industry. RE technologies is a typical high-tech, and RE development needs the national policy support, national infrastructure and the supporting of the preliminary work, that also

require government funding. The establishment of Renewable Energy Development Fund is the most effective and practical good way to use and manage government funds. The Fund has the obvious advantage of "vertical funds management": first, simple procedures and high efficiency, so administrative costs could be greatly reduced. Second, the fund can be done "unified charge, uniform issue" to ensure that RE investment companies can get the returns on time, and it can also used to encourage RE rich resource regions to develop RE. Third, China's renewable energy has entered a period of rapid growth, with the strong support of national price policy, the power generation market will continue to expand, and the amount of funds used as RE subsidy charged for the original price additional will become increasingly large, will be zoomed from the level of six billion yuan per year into the billions or even tens billion, if based upon the existing management model, it will result in a huge waste of state funds.

7.2.4 To Implement the Synchronization Connection among the Big Regional Power Grid

China has rich solar energy and wind energy resources, but rich resource regions are in the west and northwest areas, where with low load, it's the weak link of power grid, RE electricity must be transmitted to the eastern coast with power high-load areas. At present, the power grid has become a deadly bottleneck for RE development. Because RE power, especially the uncertainty of wind power, transmission of RE electricity cannot be the same as the large-scale thermal power plants, building a high-voltage transmission lines to achieve point to point transmission. RE electricity transmission, in particular the RE power generation base's transmission must realize synchronized connections and intelligent control between the big regional power grids.

Large power grid has been a trend all over the world, foreign interconnected simultaneous power grids all experienced the initial phase of the weak ties to the stage of structure gradually strengthened. Table 32 is the development of national and regional power grid situation in the world. It is precisely

because of synchronization grid, the United States and Europe have vigorously developed wind power, in Denmark, the maximum instantaneous wind load can reach 60% of full load, because she has synchronous grids support from Norway, France and Germany. Therefore, to develop new energy and renewable energy, new and higher requirements of energy infrastructure will be put forward. For example, from research and adsorbing smart grid technology, energy storage technologies, and strengthening the weak links in power grid construction to make it can accept more distributed power and RE power, to ensure the priority access for RE sources, grid needs expansion, grid scheduling and control need improvement, grid capacity and control is bound to rise to a new level, and to realize the synchronization connection between the regional power grids and intelligent control within the region.

Table 32 The national grid development of some countries in the world

Country	Power grid scale
America	North American Great Combined Power System was basically formed in the 60s of last century, whose current total installed capacity is more than 800 million kilowatts, of which synchronization power grid in eastern North America is more than 600 million kilowatts. With an area of 5.2 million square kilometers, it is the largest synchronized power grid in the world.
Former Soviet Union	The former Soviet Union, including Eastern European countries, had synchronous power grid cross the Eurasian continent, with a total capacity of 460 million kilowatts, covering an area of 20 million square kilometers.
Europe	By 2004, European electricity grid has covered more than 20 countries, an area of 4.5 million square kilometers, the present installed capacity has reached 620 million kilowatts.

In order to promote the reform and construction of power grid, RE electricity quota system implementation details should be expedited, through the implementation of the quota system to give power grid enterprises a certain quota to purchase, clearly the responsibility of the grid. At present, it's needed to combined the current market situation with China's power market mechanism, to research on negative effects, such as irrational

bidding resulted by the large-scale power generation enterprises' implementation of renewable energy quotas, a rapid expansion of the market triggered by excessive competition, to reconsider the responsibility of large-scale power generation enterprises participating the construction of new energy. Meanwhile, it's more urgent to clear grid quota responsibility targeted to the generation proportion, as well as establishment of the RE generation green certificates approved and transaction, related supervision, rewards and penalties system, to ensure the full amount of renewable energy on grid. Compel the grid companies to purchase the full generation by developing a quota system, while to compensate for associated costs of power consumption from the system of intermittent renewable energy supply, with an objective treatment of the actual existed technical, operational and management difficulties of grid enterprises full purchase, encourage power companies to increase the investment, implement the national development strategy of the grid simultaneously.

7.2.5 Establishing National Renewable Energy Center to Solve the Problem for Future Development

In the long term, it's necessary to strengthen basic research and development, public platforms R&D, and personnel training and other public service support system construction for RE development. Renewable energy is a typical high-tech industry, and its development requires a long-term accumulation of technology and talent, in order to establish a competitive industrial system, emphasis on the mastery of core technology industry, as well as the strength of the entire industry, to enhance research and development, and strengthen the foundation step by step.

At present, China has not set up research institutions and specialized engineering and technical management bodies for renewable energy, a small amount of technical strength dependent on conventional energy sector, there is still blank in many areas of RE industry. Compared with conventional energy sources, China's renewable energy professional and technical force is scattered and difficult to create a support system for technological innova-

tion, no management entities for national RE policy, planning and priorities, which is not conducive to independent technology innovation capability and industrial systems improved. If this trend continues, China won't own a complete RE industry system and national strategy targets for the RE development are difficult to achieve. In order to promote China's sustained and healthy development of renewable energy, and to construct the RE industries with independent innovation capability and strong market competitiveness, it's urgent to set up the National Renewable Energy Center. National Renewable Energy Center will take the responsibilities of RE technology and industrial management, and provide technical services of RE technology research and development, policy research, and major plans implementation:

(1) Organizing and coordinating the technology research and development

Organize RE-related R&D institutions, coordinate technology supporting of technical R&D, testing demonstration and industrialization, and gradually enhance technology R&D capabilities in RE field, provide technical support for industrial development.

(2) Research on strategies, planning and policies

Study and propose RE industry development strategy, planning and policy recommendations, analysis the technological development and industry status, provide support for the countries to develop RE regulations, policies, planning and major program.

(3) Organization and implementation of national plans

Commissioned by the national authorities, organize national plans, demonstration projects and the implementation of special projects, study and formulate work plans and implementation programs, organize project assessment, monitor project implementation, and assess the effectiveness of project implementation.

(4) Organizing industrial system construction

Research the methods of industrial organization, industrial policies of market access and regulatory, coordinate the relationship between the main industry body, organize personnel training, standard setting, testing certi-

fication capacity-building, promote the formation and improvement of industrial system.

(5) Management and coordination of international cooperation

Receive government commission to manage the international cooperation RE projects carried out by the national competent authorities, foreign governments and international organizations, and coordinate the cooperation between domestic and foreign enterprises, research and educational institutions, establish coordination and management platform of international cooperation.

(6) Statistical and information services

Conduct surveys and statistics of the information concerning RE development and utilization, equipment manufacturing, resources, technology and so on, objectively and comprehensively understand industrial development to reflect the status quo, manage related information database provide information consulting services for government decision-making, industrial development and business investment.

(7) Information exchange and dissemination

Commit to host RE forums, seminars, promotional activities sponsored by the State; establish and manage RE information website government-sponsored, authorized to release renewable energy policies, regulations, technology, dynamic, project reporting, and others.

7.2.6 Establishing and Improving Industry Regulation, Information Disclosure and the Reporting System of Legal Implementation

The RE industry development needs regulatory agency to effectively play its role in the regulatory functions, also needs to establish and perfect the government information disclosure system of industry supervision, planning preparation, project approval, pricing, etc., to ensure that all sectors of society can know government decision-making information, have access to participate in decision-making and relief opportunities. At the same time, a regular assessment of renewable energy law implementation and reporting system should be established, the State Council and provincial level energy

integrated management sectors regularly report to the same level Standing Committee on the implementation of the Renewable Energy Law, and announce to the public.

7.3 Prospect of Renewable Energy Development in 2020

At present, the financial crisis has created a deadly impact on global economic development, so does China's economic development, such as domestic energy demand, especially the demand for electricity has been in a downturn or slow recovery state. In the face of financial crisis, most of the countries in the world regard the RE development as the important measures of boosting confidence, increasing employment and riding out the low tide firstly. The EU reaffirmed the RE development objectives remained respectively 20% and 50% in 2020 and 2050, unchanged; U. S. president arranged new energy special in the rescue plan; Japan and Australia restore the RE support and subsidies stagnated for many years.

China has not only rich renewable energy resources, but also the fast-growing conditions. China's energy is coal-dominated for a long time, faced with growing energy demand and environmental pressures, the needs of clean energy development were more pressing, in the long run, only renewable energy sources can be used with a permanent condition. As General Secretary Hu Jintao pointed out, the development and utilization of renewable energy is the only way to sustainable development. Facing the new situation, we should strengthen the confidence of the RE development, fully understand the difficulty of the RE development, increase the efforts to support RE development, and regard promoting and supporting the RE industry development as the important measures of response to the financial crisis, pulling domestic demand, the establishment of new economic growth points, and promoting employment, it's also the long-term strategy to improve the energy structure, take a low-carbon development path, address climate change from a long-term perspective.

(1) Great efforts to develop new energy and renewable energy sources

The promotion of clean energy technology as an important measure to stimulate economic growth, increase support for clean energy development and accelerate RE generation project development, in the new installed capacity of electric power, clean electricity will reach 40% or even 50%, achieve a radical improvement in China's power structure by 10 ~15 years of efforts.

Therefore, it's necessary to further accelerate the wind & solar energy base construction of 10 million kilowatts wind power and million-kilowatt PV in Gansu Jiuquan, Xinjiang Hami and western Mongolia; while build 10 million kilowatts-class land-based large-scale wind power base in Hebei, eastern Mongolia and northeast, actively support the construction of 10 million kilowatts coastal wind power base in Jiangsu, as well as the construction of the distributed wind power base in coastal and central regions, the total installed capacity of wind power to achieve 150 million kilowatts by 2020.

For solar power, to build millions kilowatts PV bases in Qinghai Golmud, Gansu Hexi corridor and Inner Mongolia Erdos Seoul, northern part of Ningxia, and as well as in Tibet, Inner Mongolia, Gansu, Sichuan and Yunnan to build dozens of 10-million kilowatts PV bases, at the same time to build a number of cities grid-connected PV power generation systems in other regions, and to build several commercial demonstration power plant in the appropriate areas, and the total installed capacity of solar power to reach 20 million kilowatts or more by 2020.

(2) The implementation of smart connections among the large regional power grids

China with rich solar energy resource and wind energy resource, but the rich resource regions are in the west and northwest area, where with low load and can't consume the generation, renewable energy electricity must be transmitted to the eastern coast with high-load areas. RE electricity transmission, in particular the RE power generation base's transmission must realize synchronized connections and intelligent control between the big regional power grids. To develop new energy and renewable energy, new and higher requirements of energy infrastructure will be put forward. In order to ensure the achievement of renewable energy goals by 2020, the pace of power grids reconstruction (national network) should speed up, and the power grid scheduling and control needs should improve, to achieve intelli-

gence connections among the large area power grids by 2015.

(3) Actively promote the application of electric cars, encourage the development of distributed energy

Regarding promoting solar water heaters, rural gas and dispersed biomass power generation as a breakthrough point, vigorously develop the distributed energy resources, by the use of financial subsidies and other means, to mandatorily promote popularization of solar water heaters and other kinds of distributed energy technologies in rural areas and small towns, encourage electric cars and hybrid vehicles and other new energy automotive technology, achieve the required infrastructure construction of China's new energy and renewable energy distributed using by 2020.

(4) To strengthen international cooperation, learn from advanced, establish China Clean Energy Demonstration Special Region

Renewable energy is clean energy. In the clean energy area, the world's developed countries have advanced technology and innovative technology research and development philosophy, while China has the resources and markets. the global society is facing the same energy problem and challenge, i. e. enhancing the cooperation in promoting clean energy development and utilization between countries. Reform and opening up, China lead the country's economic development by special economic zones and achieve national strength. Facing the new situation, strengthen international cooperation, learn from advanced international experience, according to China's characteristics: The west with rich resource, itself is the energy base, establish China clean energy technology development demonstration special region; The eastern with high energy load and power load, establish clean energy application demonstration special region, Electric cars and charging infrastructure, building energy conservation and energy auditing and training, city rooftop photovoltaic solar energy systems and other distributed power, smart grid and energy storage systems, etc. , all integrated into the contents of clean energy application demonstration special region construction. Through the establishment of clean energy development and application demonstration special region, the problems of power transmission from the

west to east and the issues of speeding up the nationwide inter-regional power grid interconnection synchronization will be addressed by connecting eastern and western power grids as the economic ties. Before 2015, 1～2 clean energy demonstration special regions will be built respectively in east and west, and then 2～4 clean energy demonstrations special regions will be built by 2020, China's new energy and renewable energy development and utilization will step into a new historical stage at that time.