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Preface

Solar power industry, one of the most potential electric power industries, has a tremendous potential. Solar power is a rising industry with favorable policy circumstance. The unlimited solar resource and the numerous advantages of the solar power provide a bright future regarding to this industry.

This report is structured in five main parts. First of all, the background and the objectives of this research; second, the analysis of the necessities, the pressures, the strategic importance, and the feasibility in accelerating Chinese PV market development; third, the study of Chinese PV industry chain composition, technical status, technical innovation, and the development potentials; fourth, the summary of the current foreign and domestic PV power industry situation along with the market operation, the analysis of the constraints on the Chinese PV market, the introduction of relevant policies proposals and measures regarding to the technology development, associated industries, and the discussion of the foreground trends of the PV power industries; fifth, the advices given to "*Chinese PV Upspringing Development Plan in 2009-2012*" and the analysis of "Chinese PV Development Scale and the Profit in 2009-2020".

Acknowledgements

The research has been supported powerfully and guided by NEA, Industry & Trading Department of Policy Research Institution of China State Council, US Energy Foundation, and other departments and organizations. In several workshops, the experts, scholars and the representatives presented plenty of suggestions and instructions, to ensure the research on the track and link to the realities closely. Hereon, the sincere appreciation is sent to the contributors of experts and scholars.

The project group has consulted many experts, especially the foreign experts. The valuable advices from consultant experts made the report more rational on the structure and contents. Sincerely, the gratitude is delivered to all the contributors of the report.

Hereon, the research group sincerely acknowledges the contributions made by all the organizations and individuals who have concerned, supported and advised the completion of the research, and the colleagues who finalized the research report.

List of the abbreviations

	Full name
APS	Arizona Public Service Company
ACORE	America Council of Renewable Energy
BIPV	Building Integrated Photovoltaics
BSW-SOLAR	Bundesband Solar Wirtschaft
CDM	Cleanness Development Mechanism
CEC	California Energy Commission
CGC	China General Certification Center
CPV	Concentrating PV
CREIA	Chinese Renewable Energy Industries Association
CRES	Chinese Renewable Energy Society
DNI	Direct Normal Irradiation
DOE	Department of Energy
EERE	DOE, Office of Energy Efficiency & Renewable Energy
ENEA	An Italian Governmental Agency for New Technology, Energy, and The Environment
EPC	Engineering, Procurement, and Construction
EPIA	European Photovoltaic Industrial Association
EPSG	Electric Power Generating System
EU	European Union
GEF	Global Environment Facility
GHI	Global Horizontal Irradiance
GTZ	German Technology Cooperation Company
GW	Giga-Watt
GWh	Giga-Watt Hour
IEA	International Energy Agency
IEC	International Electro Technical Commission
ILR	Intermediate Load Range

	Full name
IPP	Independent Power Producer
IPVEA	International PV Equipment Association
IRR	Internal Return Rate
JPEA	Japanese Photovoltaic Industrial Association
kfW	Kfw Bankengruppe
LCOE	Levelized Costs Of Energy
LEC	Levelized Energy Cost Levelized Electricity Cost
LLC	Limited Liability Company
LOC	Local Controller
MCR	Maximum Continual Rating
MEP	Ministry of Environmental Protection
MLR	Ministry of Land & Resource, PRC
MOF	Ministry of Finance, P. R. China
MOHURD	Ministry Of Housing And Urban-Rural Development, P. R. China
MWe	Mega-Watt Electric
MWh	Mega-Watt Hour
NDRC	National Development And Reform Commission, PRC
NEA	National Energy Administration, PRC
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
O&M	Operation and Maintenance
PEA	Project Executive Agency
PPA	Power Purchase Agreement
PTC	Energy Production Tax Credit
PV	Photovoltaic
PVUSA	Photovoltaic for Utility Scale Applications, USA
R&D	Research and Development
REDP	Renewable Energy Development Program

	Full name
ROI	Return on Investment
RPS	Renewable Portfolio Standards
SDDC	Rural Electrification by Renewable Energy and Grid Extension
SDDH	Household Electrification by Renewable Energy and Grid Extension
SDDX	Township Electrification by Renewable Energy and Grid Extension
SEIA	Solar Energy Industries Association, US
SEPA	Solar Electric Power Association, US
SERC	The State Electricity Regulatory Commission, PRC
SETP	Solar Energy Technologies Program of DOE, US
SHS	Solar Household Power System
SNL	Sandia National Laboratory
TCE	Ton Coal Equivalent
UNDP	United Nations Development Programme
WB	The World Bank
WMO	World Meteorology Organization
Wp	Peak watt

1. Background and Objectives

1.1 Fast growth of PV industry and market across the world

By the end of 2008, the worldwide cumulative production of solar cell is 19GWp with installation capacity of 18.5GWp in total.

According to data of **Solarbuzz**, the global crystalline Si solar cells production soared up from 3.44GW last year to 6.85GW in 2008, among which the production in China mainland and Taiwan region rose to 3GWp, the global market share increased from last year 35% to 44% in 2008, and the thin film cell production grows rapidly, in 2008 it was up to 0.89 GW, with yearly growth of 123%. Based on unit of MW to calculate, solar grade poly-crystalline Si production has grown by 127% and met the fundamental demand of the PV industry in 2008, in which the American market accounted for 43% globally. The Si wafers production capacity increased to 8.3GW, with growth of 81%. In 2008 the PV industry production value in the world moved beyond USD37.1 billion, a growth of 11% from last year.

It is forecasted by Solar Outlook Navigant Consulting that due to the financial crisis, the PV cells/modules production in 2009 might undergo a negative growth and reduce to 4.9GWp; however, the industry can resume its fast growth and is projected up to 15 GWp, or even 28GWp in 2013.

1) The continual fast growth of the PV production is pulled forward by the strong demand (with low interest rate, increasing tariff, and incentive policies) and driven by the yearly comprehensive price decreasing rate of 7% in PV systems/modules. It is estimated that the expanding scale and improved producing process will generate gross profit of 30% for the PV industry.

2) According to SolarBuzz reports, in 2008 the worldwide PV installation capacity reached a record of 5.95GWp, a growth of 110% from 2007. The European market accounted for 82%, in which Spain exceed Germany via a growth of 285% and took the leadership with its annual installation capacity of 2,660MWp; the German installation capacity reached 1,372MWp, with a global PV market share of 24.6%. The US was listed in the 3rd, followed by Korea, Italy, and Japan. In the world, there are 81 countries where the PV power system being installed.

1.2 Chinese PV industry leaping growth and asymmetry of domestic PV market

In China, the PV industry started its scaling-up development in 2002 under the motivation of “National Brightness Project/SDDX Program” with a RMB 3 billion

government investment. With being driven by the fast growing market in Europe, Chinese PV industry, mainly composed of local private enterprises, grew to be the world 1st producer and exporter of PV module in 2007 via the hard endeavor in the past five years; by the end of 2007, in China there were more than 50 solar cells producers with the total 2.9GWp production capacity (among which a-Si thin film cells accounted for about 100MWp), 1,717MWp PV modules production of 28.2% globally, annual production value over RMB 88 billion, total employment of 82800 people, and total asset up to RMB 120 billion (of which RMB 50 billion is ongoing investment); therefore, such an industry has become a growing highlight in new high-tech industry and green economy. In 2008, the PV modules shipment in China moved up to 2.0GWp with a yearly growth of 16.5% and continued its leading position as the largest solar cells producer in the world.

By the end of 2008, the cumulative installation capacity of PV systems in China reached 140MWp (less than 1% of that in the world). In 2008, the total installation capacity of PV systems in China was about 40MWp, accounting for 2% of 2.0GWp PV cells production that year, which means that 98% PV cells production had to be exported oversea.

1.3 Is it urgent for China to open-up its domestic PV market? And how can such a market are explored in a scientific way?

Chinese PV industry is mainly composed of local private enterprises, which have the own growth source from European and American markets, and so far its production capacity, scale and PV cells output keeps ahead of those of other countries; but the domestic cumulative installation capacity is less than 1% of the global sum and 53.8% of such capacity is commercially applied to mobile phone communication stations and commercial power supply sources while the rest of 46.2% is in rural non-electrified electrification and some grid connected PV pilot power projects, with being financed by the government investment; the grid connected power applications (BIPV + ground PV stations) account for 20% only and the rest is off-grid PV systems.

Facing the increasing severe pressure from energy sources and environment protection, the Chinese government has to weigh the option of supporting large scale domestic PV market development via incentive policies and fiscal subsidy just as what some European countries, US and Japan have done, based on the current expensive PV power cost. It is in dispute, a deputy of NPC[1] pointed out that “Chinese large scale exporting of PV modules is to supply the green energy and power to others and keeps pollution, and it is not a wise practice”, while some others said “China is a developing country, so China can make use of European and American

[1] NPC - National People’s Congress

market to foster the Chinese PV industry. As the PV power relevant cost descends to an acceptable level, China can start up the Chinese local development in large scale".

Generally speaking, the public have a view: solar energy will be the main source of human being; PV power generation is growing fast to be a vital RE power technology, and Chinese PV power industry is bound to be an essential part of the power system; the essence in the dispute is how to define a scientific developing roadmap for Chinese PV market, and how to schedule in PV industry development scale and growth speed, and how to plan on the critical market regions, and what is the bottleneck in terms of the relevant technology and policies, and how to implement the plans, in a word, the question is how to scientifically explore our domestic market.

With the sudden coming of global financial crisis, the PV industry in China is facing unprecedented pressure: the stock of some listed companies has shrunk sharply; a certain number of small enterprises has been closed; the European and American markets supported by the government policies have a great risk to shrink due to the capital shortage; more and more pressure has occurred to Chinese enterprises because of the exchange rate volatility and unstable capital returning. All these factors are clouding the Chinese PV industry, which was over-relying on the foreign market.

However, on the other hand, the central government's policies in pulling internal demand, restructuring the industry, supporting RE development have given the opportunities for Chinese PV industry and market to advance in a healthy and sustainable manner. Especially, the government organized the bidding of the 10MWp PV project in Dunhuang in Mar of 2009, and the recent two official documents of implementation guideline on accelerating solar PV building integral applications in MOF Construction [2009] No 128 and No 129, co-issued by the Ministry of Finance and the Ministry of Housing & Construction, have signaled to the world on Chinese active promotion of its domestic PV market.

In this report, the objective is to analyze the strategic status and current situations of PV power generation in the electric power energy structure based on the actual conditions in China, and accordingly, recommend relevant proposals in principle of sustainable development to scientifically develop the local domestic PV market, so that the government and authorities involved can use this report as a reference for drafting some relevant industry policies.

2. The Necessity and Urgency of Accelerating of Chinese PV Market Development

2.1 Renewable energy and industry revolution[1]

Energy is energy- carrying resource which directly, or indirectly supplies, by converting the energy into light, thermal energy, and power, and any type of the energy, all the energy on earth can be attributed to the energy produced by solar thermonuclear reaction, the energy stored in formation process of earth, and the energy from movement of solar system.

Natural energy and resource are the important substance basis of human improvement and development.

First global energy transformation, from woods to coal, is driven by British industry revolution started in 1960s. Coke was used to smelt iron in British in 1709, Watt invented steam engine in 1765 and the first railway in the world put into operation in 1825. Metallurgy industry and steam engine drove the industry revolution of British, Germany, U.S, France, Russia and Japan. Coal industry is the power basis of the above industries development.

In 1920s, the second global energy structure transformation began, from coal to oil and natural gas. Developed countries leaded by United States transferred the energy style from coal use to the use of oil and NG of high efficiency and high heating value, as ideal chemical industry material which are easier to process, transform, transport, store and use, by relying on the technology improvement. In 1950-60s, lot of countries achieved the rapid growth of economy by relying on sufficient and cheap oil. Fossil energy utilization drove the rapid development of modern science and technology and promoted society improvement to a new unprecedented degree. Human can get rid of the gravity of earth and fly to other planet. Current labor efficiency of agriculture production and industry process is thousands and hundreds times of ancient times. The signal and image can be sent to anywhere of the earth. By means of energy, capability of human master natural has reach unprecedented level. Electricity production and rapid application development promoted society development. Modern society could not be separated from electricity for a while.

From the beginning of 1970s, the third global energy structure transformation began, from fossil energy to sustainable energy system based on renewable energy. There are three reasons: the first is limitation and non-renewable of fossil energy, the global total proven-up resource quantity of coal, oil, NG, and Uranium, and oil shale can only be used by human for more than 100 years; the second is the increasing severely environmental issues caused by fossil energy utilization, the rapid increasing

pollutants emission is closing to the limit of environmental condition for the human existence, the gross amount of the emission must be limited, so as to sustain the ecological system being the benign cycling situation; the third is that the of majority of the current energy system is fossil energy, which result in the centralization of the capital and control right, scramble for resource and monopoly market introduce more and more political and social issue even war because of fossil energy dominated energy structure.

The establishing of the sustainable energy system, based on renewable energy, will radically eliminate the disadvantage of fossil energy system and build harmony between human and nature，and promote the harmonious development of the human society. At present, we are in the transitional time of the third revolution of energy .

The above-mentioned three phase of energy structure transformation is shown in Fig2-1. Dotted line, red line, green line respectively represents total energy consumption, fossil energy and renewable and new energy.

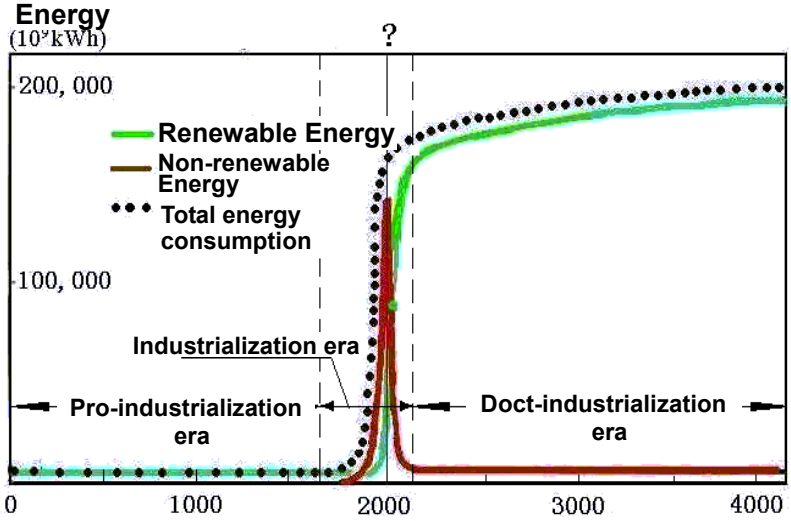


Fig2-1 Transforming process of energy

Although the human civilization has acquired rapid development in past 200 years, majority of fossil energy accumulated in 4.6 billion years on earth has been consumed at the striking speed of consumption. In the past 20 years, global annual energy consumption grew at 3% and world per capita energy consumption grew from 1.871TCE in 1970s to 2.143TCE in 2004, the developed OECD countries per capita energy consumption is 5.49TCE and non-developed countries per capita energy consumption is only 0.75TCE, United States and Canada are over 11TCE per capita energy consumption; Russia, Japan, Germany, British and France are around 6TCE; It is around 2TCE in China. According to World Energy Commission (WEC) forecasting, according to the proven-up reserve and the current speed of energy consuming, petroleum can only be used for another 43 years, natural gas is 66 years, and most abundant coal only can be used for another 169 years. It is has been put on

agenda about the way to assurance human energy sustainable supply.

The past 100 years experienced the fastest development in the history, world population increased by four times, industry production increased by 50 times and energy consumption increased by more than 100 times. But development has its two aspects. We awkwardly find that human being is facing the ten severe environment problems: ① global warming, ② Ozone layer damage, ③ bio-diversity reduction,④ acid rain spreading, ⑤ forest sharply reducing, ⑥ land being deserted, ⑦ air pollution, ⑧ water pollution, ⑨ ocean pollution, ⑩ solid wastes pollution. Above -mentioned problems are all the results of excessive usage of fossil energy. Environmental problems challenge human's survival on the earth. Finally, people have realized that it could not last forever that economy and social development is at the expense of environment.

Future sustainable energy system, based on renewable energy, includes solar energy, geothermal energy, hydro energy, wind energy, hydrogen energy, ocean energy, biomass energy and nuclear fusion and nuclear fissile reactor, etc. It is a long time of process converting into the energy system with majority of renewable energy. Experts estimate that it may take more than 100 years to complete the process. However, the environment deterioration, global warming, conflicts or wars for occupying and controlling the fossil energy resource, have urged the human being to take active actions, in order to improve the energy system, to decrease the emission. At present, in the world, the acts of promoting renewable energy development in every nation are on the upsurge progressively. Under such circumstance, the clean energy mechanism and the energy system with majority of renewable energy are expected to achieve the target ahead of schedule. In 2050, the target that more than 50% of energy is from the renewable energy in the world energy system, see also Fig 2-2.

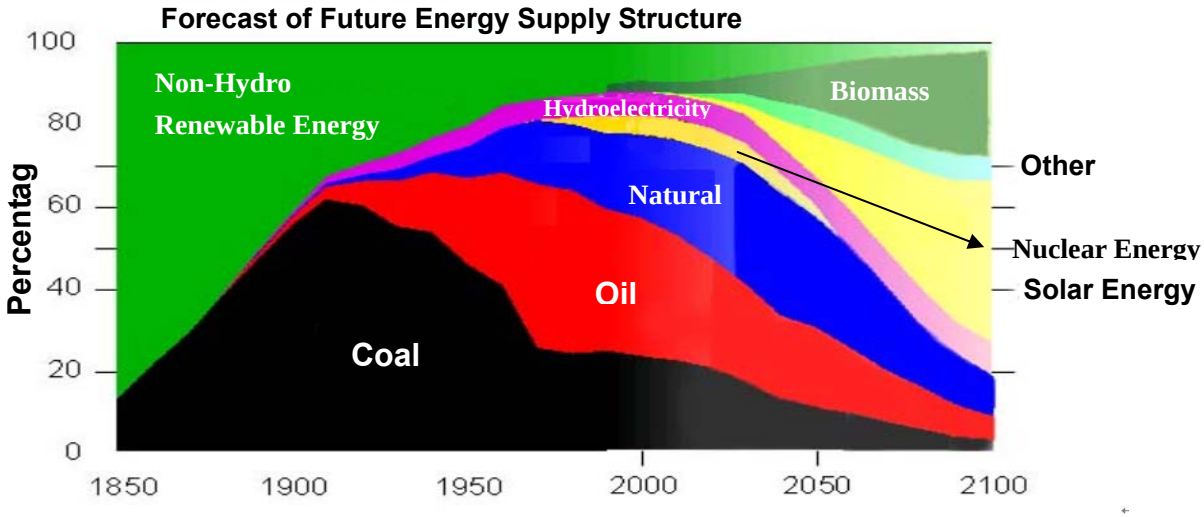


Fig 2-2 Trend of energy composition changing

With retrospection of the origin, renewable energy is from sun. Total radiation energy from sun is about 3.75×10^{26}W, while 1.7×10^{16}W arrives on the surface of the earth, which is equal to more than 35,000 times of present world energy consumption. With regard to the solar radiation arrived on the earth, 0.015% of the solar energy can be absorbed by the vegetation only 0.002% solar energy is utilized by people. The current utilization rate of solar energy is very little; the solar energy potential is unlimited. It is clear that hydro energy, wind energy, biomass energy, and geothermal energy are indirectly from solar energy. From the view of energy potential, solar energy is the most potential resource in renewable energy.

With science and technology improvement, renewable energy technology is now experiencing unprecedented development speed and application scale is greatly expanded. As the cost of fossil energy grows rapidly, the cost of renewable energy is now getting closer to cost of fossil energy. Many countries gradually strengthen to support and promote renewable industry development, accelerate the cost declining of renewable energy. Development of distribution electric power source and new energy storage technology will meet the requirement of power grid in which renewable energy is the major and stable electric power source.

Fossil energy will be used up in next 100 years, and people will begin the era of renewable energy, with substituting fossil energy. China per capita energy possession amount is far lower than that of world average, the energy consumption grows rapidly and environment emission capacity is almost up to the limit. If the economical and social sustainable development and energy security are to be sustained, greatly developing renewable energy is inevitable choice in China.

Large scale development renewable energy is not temporary expedient for China. It has essential to solve energy and environment sustainable issues to re-developing China and building the well-off society. It is the only way for renewable energy to substitute the fossil energy. Renewable energy is the basis of post-industrial era; whoever masters advanced renewable energy technology will occupy the high position of future industrial revolution and will lead the post-industrial era. PV power, as one of important solar energy utilization, will play an important role in the third industrial revolution.

2.2 PV power plays key roles in the electric power and the sustainable development in China

1. Chinese energy and environment face huge pressure

With rapid urbanization and industrialization in China, energy shortage and environmental pollution have become the two prominent issues constraining the Chinese economy and social sustainable development.

The rapid economical and social development in China speeds up the growth of energy demand. Energy supply gap is bigger and bigger and became the constraint of social and economy development. In China, the primary energy consumption has grown from 1.04 billion TCE in 1990 to 2.85 billion TCE in 2008, and China became the second largest energy consuming country [2].

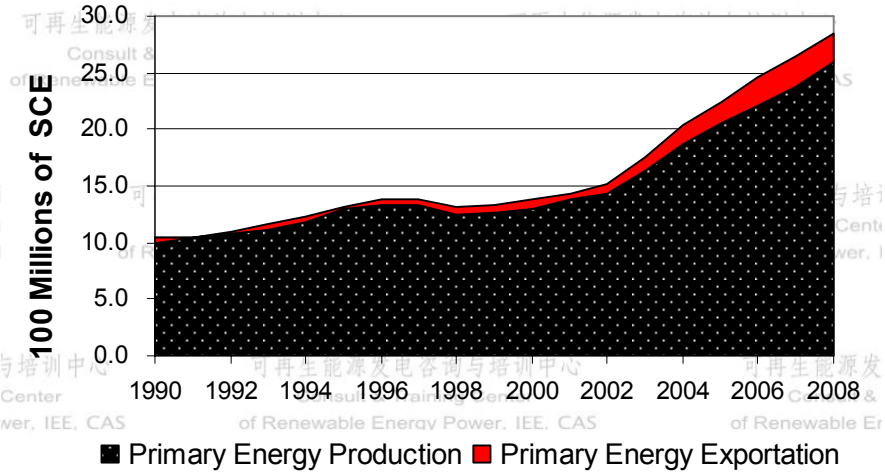


Fig2-3 Comparison of China primary energy production and exportation
(Source：China Statistical Year Book by National Bureau of Statistics)

China has comparably plenty of fossil energy reserve, coal is the major, the reserved quantity of coal is 1034.5 billion ton, left discovered reserve is 13% of the world, ranks the third place; oil reserve is 21.2 billion ton, and natural gas is 2.2 billion cubic meter. Due to large population, per capita fossil energy possession quantity is low, per capita possession of coal is only around half of the world average, and that of petroleum and natural gas is around 1/15. China faces much more serious fossil energy situation than that of other countries. [3]

China is a huge energy-consuming country, and ranks the second place in the world next to United States. But, China is still a developing country, energy per capita consumption is quite low and lags behind the developed countries, there is still big energy growth space and energy consumption growth speed is relatively high. China per capita energy consumption is only 1,316 kilogram standard oil equivalent, 26% of world average energy consumption 1,778 kilogram standard oil equivalent, only one third of Japan, one sixth of United States [4], sees Fig 2-4. With progress of the well-off society construction and improvement of industrialization and people's life, energy demand will increase continuously.

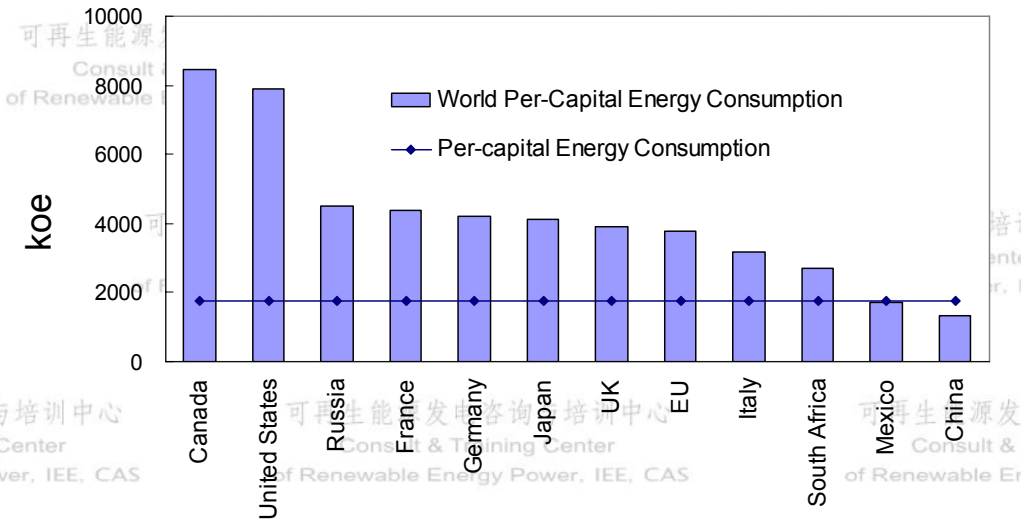


Fig 2-4 Comparison on per capita energy consumption of individual country in 2005

The major energy resource in China is coal. Total primary energy consumption in 2007 was 2.65 billion TCE, and the percentage of coal is 76.6%, 40% higher than world average. 53% of coal was used to power generation [5], this energy consumption structure has severely influenced on environment. In 2007, the major emission pollutants are as follows: SO_2 was 24.681 million tons, soot was 9.863 million tons, and industrial dust was 6.99 million tons [6]. According to the statistics, 70% of soot emission, 85% of SO_2 emission, 67% of nitrogen oxides emission, and 80% of CO_2 are from coal combustion. Currently, the energy environment issues, which China is facing, includes: 1） severe acid rain of the SO_2 resulted from the coal combustion, the land area with acid rain occurring accounts for 1/3 of the total area; among the 500 cities or counties monitored, there were 281 cities occurred the acid rains, which account for 56.2%; 2） due to the coal-firing, the CO_2 large amount emission brings about the greenhouse impact and global warming, since 1970, the CO_2 emission quantity in China has been the first large in the world.

2. Power energy structure needs to be changed urgently

In China, the power generation still heavily relies on thermal power. In China, the total power generation is 3433.4 billion kWh, the growth is 5.15%; the increasing degree fell back in the recent years. Where, thermal electricity is 2779.3 billion kWh, with 80.85 % of total power generation, see Fig2-5[7].

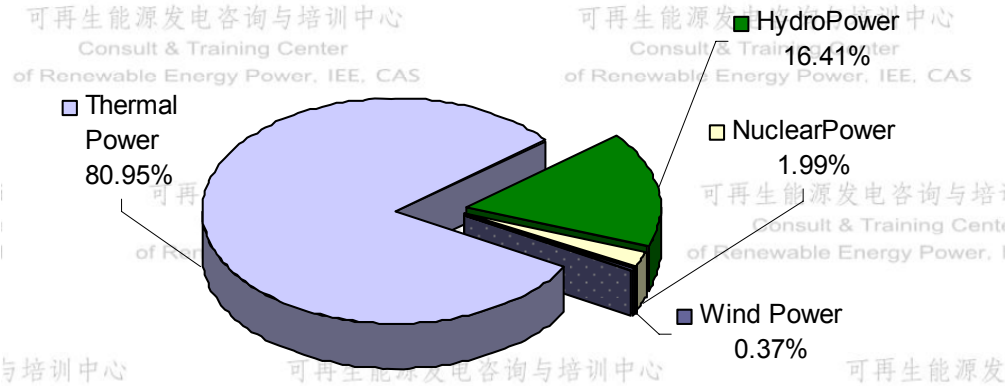


Fig2-5 Chinese power generation profile in 2008

Though the renewable energy is strongly appealed in China, and the proportion of clear power has been increased a lot, thermal power dominate the power energy profile all through. As shown in Fig2-6, the thermal power proportion has risen from 79.8% in 1990 to 80.95 % in 2008. Thermal power proportion is not lowered down, but instead grew up; the proportion of clear power still keeps lower in power structure.

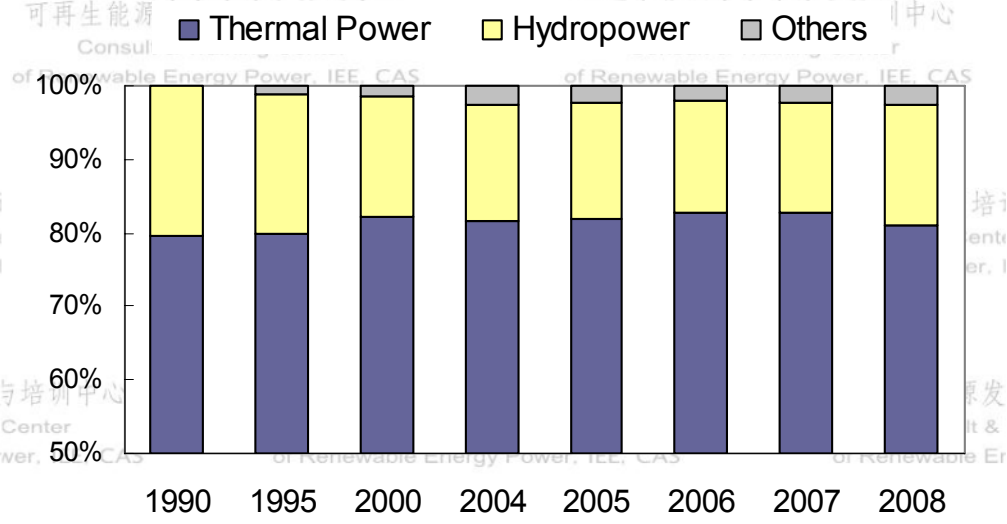


Fig 2-6 Power generation components in recent years

As shown in Fig 2-7, comparing with other countries, Chinese thermal power proportion is the highest. According to the statistics[8], Chinese thermal power proportion is much higher than that of United States, and 15% higher than that of world average thermal power. Chinese thermal power is mainly coal-fired power, approximately 80% of it, however in the developed countries, the thermal power includes the considerable oil power and natural gas power besides coal-fired power, the oil power and natural gas power are clearer and less emission than that of coal-fired power generation. For example, the thermal power in U.S. accounts for 72%, in which the coal firing power generation is 70% and oil and NG power of 30% or so. Therefore, Chinese electrical power generation profile will be more irrational and has more influence on the environment.

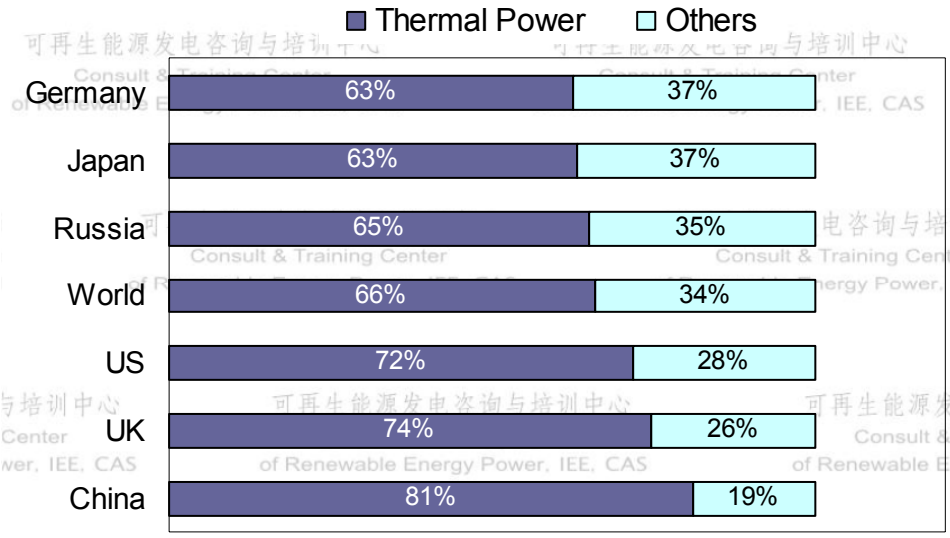


Fig 2-7 Power generation portion by country in 2007

3. PV power plays an important role in future power structure

Since first solar cell was produced in 1954, PV industry has achieved the significant improvement. With the technology improvement, solar cell efficient has upgraded from 6% at initial to 42.8% in laboratories [9]. PV application has expanded from satellite power source to home power supply and grid connected power plant. With market scale expanding, the increasing of the R&D funds, and the accumulation of the practice, the cost of PV grid-connected power gradually decreases from more than RMB 10/kWh in 1980s to present RMB 1.5-3 /kWh. PV industry has experienced rapid development; average growth rate in recent five years is over 40%. By the end of 2008, global accumulative PV installation capacity was 18GWp.

In 2004, Europe Renewable Energy Council released *Renewable Energy Scenario in 2040*, it stated that in 2040, 80% of world electricity consumption will come from renewable energy and the percentage of PV power in renewable energy electricity will achieve 31 % and PV power generation will be 9,100TWh in 2040[10].

In 2006, Green Peace and EPIA has forecasted in the report that global PV installation will reach 433GWp in 2025 and PV power generation will be 586TWh.

EU has set the development target of 2010 in *European Union Strategy and Action Plan White Paper*, that the solar PV power installation capacity will be 3GWp in 2010[11].

United State new president Obama declared, as his came into power, that renewable power will account for 10 percent in 2012 and 25% in 2025 total United States electricity consumption, including solar energy, wind energy and geothermal energy. In order to reach this target, USD 150 billion will be invested in renewable energy next 10 years.

In July, 2008, Japan Council of Minister has passed *Low Carbon Society* [12]and pointed out that PV power generation in 2020 will be ten times of that today and 50 times in 2030 that of present. At the end of 2008, Japan accumulated PV installation capacity is 2.1GWp[12].

In 2007, *The Chinese Medium and Long-term Renewable Energy Development Plan* was released by NDRC, to accelerate renewable energy development and cut down the coal proportion in energy consumption structure. Moreover, the target will be set that renewable energy consumption will be 10 percent of the total energy consumption in 2010 and will be 15 percent of total energy consumption in 2020. Solar energy is an important part of renewable energy; the target is that solar PV power installation capacity reaches 300MWp in 2010 and 1.8GWp in 2020 respectively.

4. Special role of PV power in the non-electrified area electric power construction

During the period of 8th and 9th 5-year plan, total installation capacity of 420 kW PV power project- "Tibet no-water energy resource PV power plant construction" ended the history of no-electricity in seven counties of Tibet. In 1997, the State began to implement "Brightness Project Program" to supply power for remote non-electrified areas by PV power system and wind energy system. In 2002, the State began to implement world–famous SDDX program, around 700 townships' electricity supply problem was solved by PV power plants. In addition, China and foreign cooperation projects also adopted PV technology to supply power in remote region, such as GEF/WB China PV market developing plan, UNDP China PV project, and Japanese NEDO PV project in China, Silk Road Brightness Project, and Sino-German Financial Cooperation PV project. The implementation of these projects has promoted PV large scale application in China and rural electric construction and improved local residents' living standards.

In 2007, *The Chinese Medium and Long-term Renewable Energy Development Plan* was released by NDRC, in which by adopting PV home system and mini-grid PV power plant to supply power to remote areas and the no-electricity residents in key regions Tibet, Qinghai, Inner Mongolia, Ningxia, Xinjiang, Gansu and Yunnan. The target is to build 100MWp PV power system to supply power to one million households' herders and farmers in remote areas. In 2010, total PV installation capacity in remote rural area reaches 150MWp in 2010, 300MWp in 2020.

At the beginning of 2009, National Energy Administration (NEA) has released "*Energy* Prosperity *Plan*" in which power supply for two million no-electricity people by PV power plant and solar home system was presented out once again in accordance with the local situation.

2.3 China electric Power development demand forecast

1、 Prediction by the expert of Chinese Academy of Electric Power

With considering factors such as electricity elasticity coefficient and economy development trend, expert of Chinese Academy of Electric Power forecasted that Chinese electricity production capacity will increase by 800GW from 2009 to 2020, which means annual increment is 66GW and the 2002 power generation will reach 1.6TWh[13].

2、 Prediction by the expert of Chinese Associate of Electric Power Enterprises

In 2007, Zhao Xizheng[14], the chairman of Chinese Associate of Electric Power Enterprises, pointed out that total electricity consumption in China will exceed 6000 billion kWh in 2020.

3、 Prediction by this project team

Electricity consumption elasticity coefficient is the ratio of electricity consumption growth average rate to gross domestic production average growth rate. Based on electricity consumption elasticity, future electricity demand can be forecasted on macro level. The expert of Price Monitoring Center of NDRC pointed out that the electricity consumption elasticity should fall into the range between 1.0 and 1.2[15]. This project team takes 1.1 as electricity consumption elasticity to forecast future electricity demand.

With rapid growth of Chinese economy, electricity per capita consumption increased from 1,084 kWh in 2000 to 2,598 in 2008, annual increase rate is around 11.5%.

In 2007, 17th China Communist Party Congress put forth that China per capita GDP will quadruple in 2020 over 2000. Assumed that electricity elasticity coefficient to be 1.1, China per capita electricity will raise up from 1084kWh in 2000 to 4770kWh in 2020. *Chinese Population 10th Five Years Plan* set a target of population control with less than 1.45 billion in 2020. Then, it can be calculated that the total electricity consumption in 2020 is about 6,915TWh. According to our forecast, per capita electricity consumption annual increase rate is 5%, which is only half of increase rate in 2000- 2008.

The long-term development target in China is comprehensively well-off life in 2050, which means medium developed countries level. Per capita electricity consumption South Korea is 7803kWh, which accords with the medium development country level. The number can be taken as the reference target of China per capita electricity consumption, as China can attain the level of the medium development country in 2050. According to the prediction by UN Population Foundation, there will

be a great change of population in 2050; in 2050, the Chinese population will be 1.4 billion or so. For it, is can be deduced that in 2050, Chinese total society electricity consumption will be about 10900 billion kWh, in accordance with the predicting of this project team, the per capita electricity consumption growth rate will be 1.71% in 2020-2050.

Tab 2-1 Chinese electricity demand forecast of 2020- 2050

Year		2005	2020	2050
Thermal power	Power generation（0.1TWh）	20,437	48,287	49,000
	Installation Capacity (10MW）	39,137	96,574	98,000
Hydro-power	Power generation（0.1TWh）	3,970	10,500	11,200
	Installation Capacity（10MW）	11,739	30,000	32,000
Nuclear power	Power generation（0.1TWh）	530	2,530	12,000
	Installation Capacity（10MW）	684	4,217	20,000
Wind power	Power generation（0.1TWh）	27	630	5,250
	Installation Capacity（10MW）	106	3,000	25,000
Biomass	Power generation（0.1TWh）	110	1,200	8,000
	Installation Capacity（10MW）	220	3,000	20,000
Solar power	Power generation（0.1TWh）	0.2	27	1,500
	Installation Capacity（10MW）	1.5	180	10,000
Electricity Demand（0.1TWh）		24,940	69,150	109,242
Gap（0.1TWh）		0	5,976	22,292

This project assumes that the equivalent power generation hours of thermal power , nuclear power, hydro power, biomass power, wind power and PV power is respectively of 5000, 6000, 3500, 4000, 2100, 1500, from which the power generation quantity of different power technologies can be obtained at the same power capacity of installation, sees Tab 2-1. If by 2020, the targets of the renewable energy in "*Chinese Medium and Long-term Renewable Energy Development Plan*" and targets of the coal power generation and nuclear power generation set by the expert of Chinese Academy of Electric Power can be reached in 2020, the sum of power generation of the two items is 6317.4 billion kWh, which can not meet the total society

electricity demand of 6915 billion kWh predicted, with a lack of 597.6 billion KWh. Our prediction for the electricity use in 2050 will be 10904.2 billion KWh. The installation capacity in the long term vision plan [16] is 8695 billions kWh, with an electricity gap of 2229.2 billion kWh.

In the past, generally, as the power supply is urgent, the electrical power administration fill the electricity gap by accelerating the building of the coal firing power plant. However, in the future, due to the coal price increasing, the coal fired power cost will increase accordingly. Meanwhile, the large scale of coal burning will quicken the environmental pollution further, the continual developing of the large scale coal –fired power shall be confined. The solar PV has its superiority of environment and resource and the PV power cost is decreasing quickly. With the consideration of different proportions of PV power, if 30% of the future electricity shortage in 2020 is filled by PV power, the installation PV power capacity shall be up to 120 GWp, the equivalent installation power capacity is about 40GWp; if 50% of the future electricity shortage in 2020 by PV power, the installation PV power capacity 190 GWp, the equivalent installation power capacity about 62GWp; if 70% of the future electricity shortage by PV power, the installation PV power capacity 270GWp, the equivalent installation power capacity about 90GWp. Forecasting conservatively that, in 2050, id the 20% electricity is from PV power, the installation PV power capacity will be 5,800GWp, the equivalent installation power capacity about 1.9 TWp, see also Fig2-8.

The PV equivalent installation capacity refers to the equivalent capacity of coal fired power, being same as the power generation of a certain capacity of PV power plant, i.e. under the condition of coal fired power full load operation time is 5000 hours per year, and the PV power full load operation time of 1500 hours per year, the equivalent PV power installed capacity can be got, with PV power installed capacity being multiplied by 0.3. e.g. the power generations of 1kW PV power system is equal to that of 0.3 kW coal fired power plant with 5000 hours operation, therefore the equivalent of 1kW PV power system is 0.3 kW.

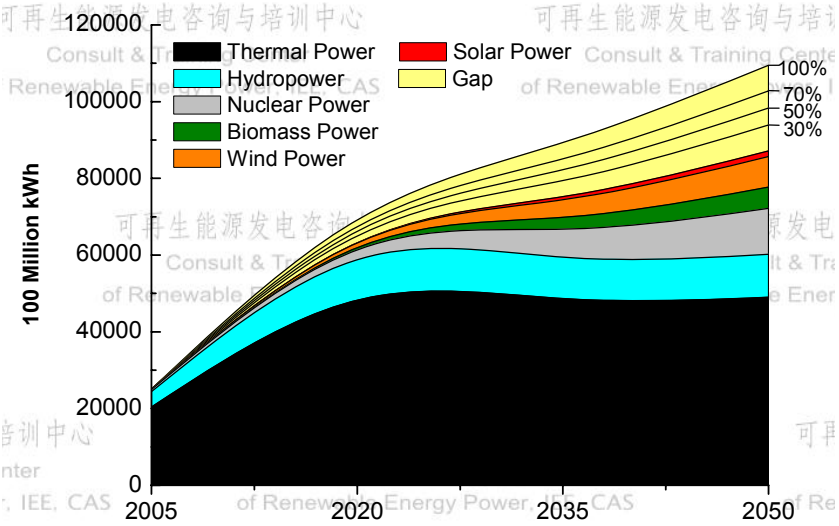


Fig 2-8 Whole society electricity demand and energy increasing prediction in 2020-2050

2.4 Full cost analysis of Coal-fired power

1. Current coal-fired power cost

According to the 2007 report of State Electricity Regulatory Commission (SERC), the total electricity generation in China is 3255,9 TWh, and the thermal- power is 2698 TWh, which is 82.86 percent of total power generation.

Average feed-in tariff of power generation enterprisers was RMB 336.28/MWh, increased by 1.74% from that of 2006. Average sales price of grid companies was RMB 508.51/kWh, increased by 1.84% from that in 2006; Average purchase price of grid companies was RMB 348.39/kWh, increased by 0.89% from that in 2006. Growth range of feed-in tariff of power generation enterprises is much less than that of power generation cost, which results in loss of electricity producers.

Based on the data, whichever of the feed-in tariff and the sale price of electricity are higher in east than that of west in china, south is higher than that of north. This unbalance accords with the distribution of fuel cost, economy development level and power plant.

At present, the coal price in China is marketized, but tariff is still controlled by the government. Present low tariff couldn't reflect real cost of coal fired power. In the long run, it is not favorable for the energy-saving, emission reduction, electricity energy structure optimization, and electric power industry development.

2. Present coal-fired electricity real cost and trend

By the end of 2007, there are more than 4000 various power generation enterprisers over 6MW capacity, state-owned and state owned stock holding enterprises account for 90%. The central directly affiliated power generation Group, such as China Huanneng Group, China Datang Group, China Huadian Group, China

State Power Group, and China Power Investment Cooperation, account for 41.98% of total installed power capacity in China.

Power generation, feed-in electricity, and operation cost of Datang Group and Huaneng Group in 2007 are shown in Tab 2-2.

Tab 2-2 Power generation of Huaneng and Datang Group Co, Ltd in 2007

Company	Huaneng	Datang
Power generation（0.1TWh）	1,736.88	1,182.71
Total operation cost（RMB 100 Mio）	417.06	236.10
Per-capita cost（RMB/kWh）	0.24	0.20

The coal-fired power cost exclusive of the external cost is calculated based on annual report 2007 of Huaneng Group and Datang Group Co,. Ltd. The operating cost of thermal power includes fuel, maintenance, depreciation, labor and others. Coal-fired electricity cost is RMB 0.22/kWh, based on the comprehensive cost data of the two power generation groups.

The external cost does exist in coal mining and utilization. According to the *Real Cost of* Coal released by Green Peace in 2008, external cost of coal mining, transport, and the utilization was up to RMB 1745 billion, accounting for 7.1% of GDP. This report also pointed out that 53% of coal was used in the power generation, so 53% of the external cost should covered by coal-fired electricity. Based on total power generation of 3698 billion kWh in 2007, average converted external cost of coal-fired power is RMB 0.343/kWh. Therefore, the real cost of coal-fired power including external cost shall be RMB 0.563/kWh.

According to the standards of EU countries, external cost of coal-fired power including the air pollution effect on human health, acid rain, and agriculture production decreasing is Euro 6-8 cents per kWh[17], with being converted to RMB 0.52-0.69 Yuan/kWh, that is over 50-100% than RMB 0.343 Yuan/kWh. With Chinese growing severely environment problem, external cost of coal-fired power grows inevitably and rapidly. Heron clarify that Euro70 /ton carbon dioxide emission cost of coal-fired power had been covered in calculation.

3. Trend Analysis

It is recognized world widely that annual growth rate of cost of thermal power is 4-7%. The State Electricity Regulatory Commission analysis on the operation cost for five key electric power groups that the cost of unit power generation increased by 8% in the first quarter of 2008 from the same time of 2007[18].

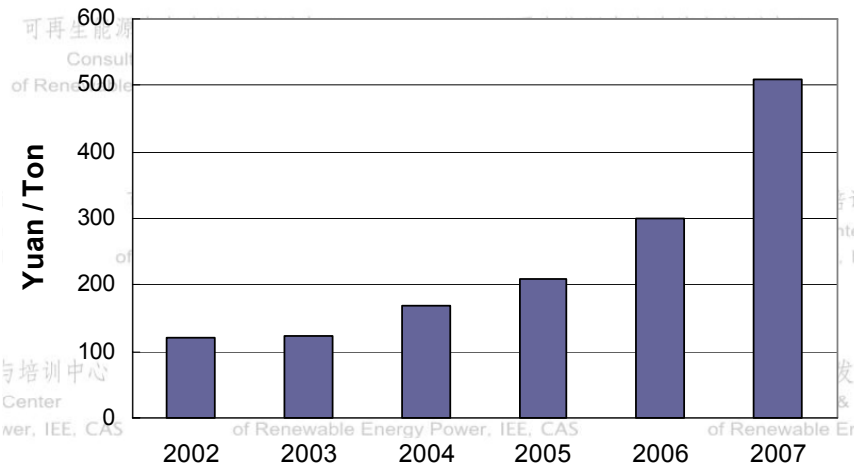
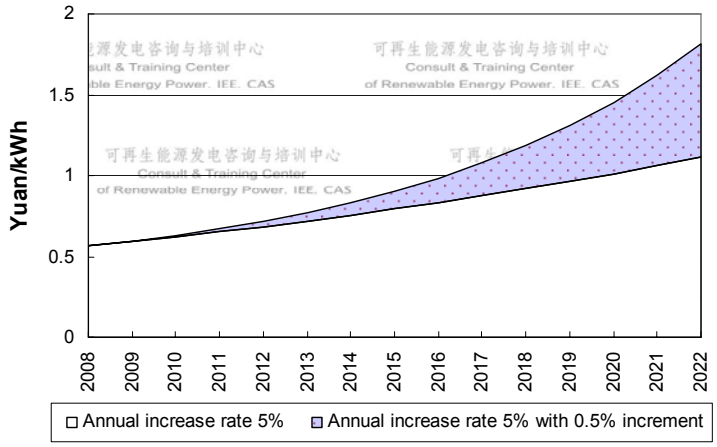


Fig 2-9 Changing trend of coal average price in China

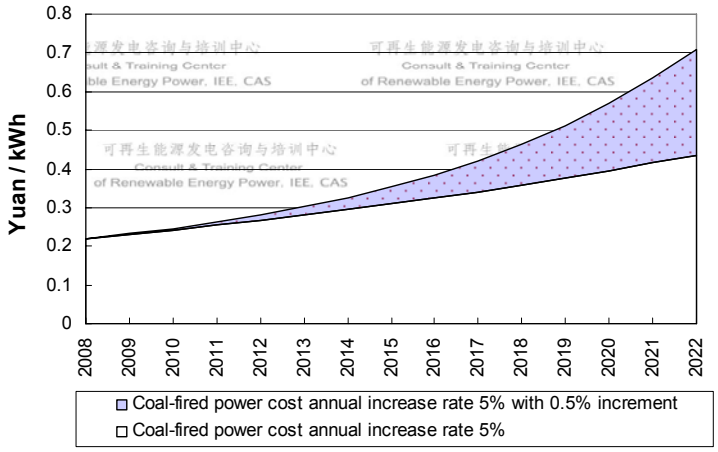
Variation of thermal power cost mainly related to fuel cost, labor cost, and finance expense, fuel cost is about half of power generation cost. From 2002 to 2007, average coal price has climbed from RMB 121Yuan/ton to RMB 507Yuan/ton at a rate of 33% annual increase, see fig2-9[19]. Increasing rate of coal price much exceeds over that of feed-in tariff, which results in serious loss of electricity production enterprisers. In 2009 *Central Government Work Report* was mentioned that the continual deepening of the tariff reform shall be done, the formulation mechanism of feed-in tariff, tariff of transmission and distribution, and the sales tariff shall be improved gradually, and the coal price and the electricity price relationship shall be smoothened in time. With the reforming of tariff, price of coal-fired electricity will grow, being followed by coal price rising. Although the coal price is falling down due to impact of the financial crisis, but for the limit coal reserve and the increasing of the demand of coal in the future, in the long run, coal price will grow.

Due to more and more severely environmental issues, the strengthening of the environment protection, the increasing of the investment on environment, the external cost of coal fired power generation will increase continuously.

This project team forecasted that annual increase rate of coal-fired power is fluctuated within the range of 5% and plus 0.5% increment. If the tariff policy covering the external coal-fired power cost is released, the cost of coal-fired power grows as shown in A, otherwise, it grows as shown in B.



（A）



（B）

Fig 2-10 Coal fired power cost and the changing trend inclusive of external cost

2.5 International status of present China PV industry

1. Chinese PV industry status

Through the six years rapid development, China became the biggest country of solar cell and PV module manufacturing in the world in 2009. PV module accounts for 28.2% of production in the world, the sale revenue of PV industry was over RMB 88 billion, and the employment in PV industry was over 80,000 people.

There are about 50 enterprises investing on poly-crystalline Si manufacture, with the total scale of over 10,000 tons and the investment of over RMB 100 billion. Preliminarily estimating, the production of poly-crystalline silicon in 2008 was 4500 tons. By the end of Jan, 2009, production capacity was put into operation of 21000 ton/year, and the planning production capacity is 26000 ton/year.

The number of ingot and wafer manufacturer is over 60. Based on preliminary estimate, production of ingot and wafer reached 20000 tons.

The number of solar cell manufacturer is around 60. Available production

capability formed in 2008 was 5.0GWp. Solar cell production in 2008 is 2.0GWp, being ranked the first in the world. In 2008, eight enterprisers were listed into the top 25 PV manufacturers.

In the PV module field, there are about 330 manufacturers with 5.0GWp production capability. PV modules production with 3GWp accounted for 44% of global production, with being ranking on the first in the world.

2. International PV Industry status and trend

In 2002-2007, the average annual growth rate of global solar cell production was 50%, and the PV industry became one of fastest growing fields. Global solar cell production was 6,4GWp in 2008, increased by 50% than 2007. Solar cell manufacturers mainly distributes in China, Japan, Europe and United States, see fig 2-11[20]. According to statistics, global PV industry production value was USD 37.1 billion in 2008[21].

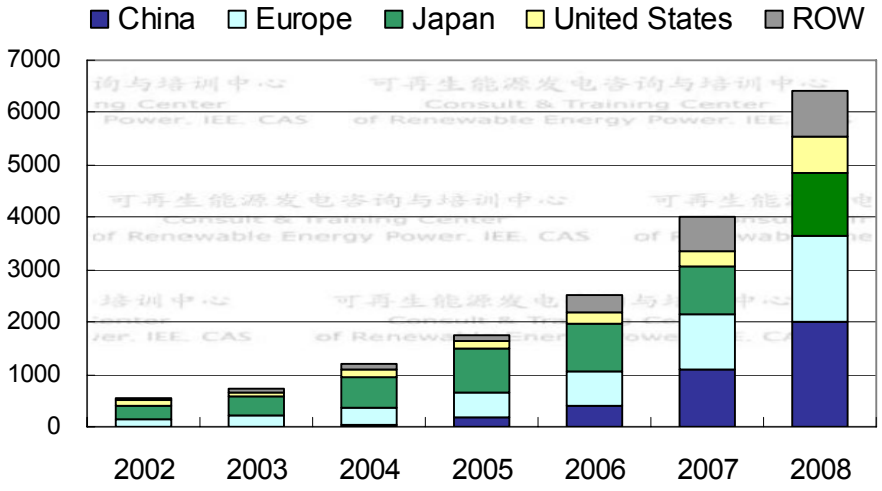


Fig 2-11 Solar cell production distribution in the world

According to the forecast of some international agencies, by 2010, the PV industry production value will be up to EUR 40 billion, and the PV market will be ranged of 6-17GWp and solar cell production capability will reach 35GWp in 2010 due to the production formed and planned[22]. This shows that the most optimistic market expectation could not consume solar cell production capability, with rapidly increasing.

From the beginning of this century, PV industry has experienced a rapid development phase. In past few years, the global average annual increasing rate was about 40%, and the total installation capacity rose from 600MWp in 2003 to 5950MWp in 2008, among which Spain, Germany, United States, Japan, Italy and Korea are the majority of the PV module installation capacity, with accounting for 91% of the total installation capacity, see Fig2-12 [23]. The fastest growing market in 2008

is in Spain with 2.46GWp, over 1.8GWp in Germany.

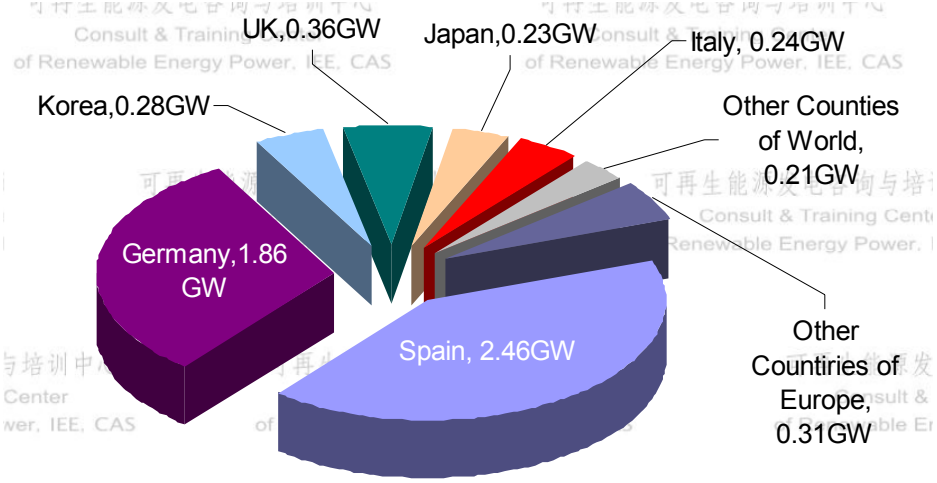


Fig 2-12 World PV market profile in 2008

3. Chinese PV industry orientation in the world

By introducing, digesting, and absorbing the international advanced technology, poly-crystalline silicon purification technology of China has been on the top in the world; the waste gas recovery and reuse and the zero emission were realized. The issue of poly-crystalline silicon shortage will be solved in near 1-2 years.

Ingot-casting and processing technology of mono-crystalline silicon and poly-crystalline silicon already reached international advanced level. Mono-crystalline silicon growth furnace localization has already been gained; the casting furnace of poly-crystalline silicon is being localized.

China solar cell production technology is close to the world advanced level. Some excellent solar cell producers have attained the international advanced level. In 2008, China was still the first largest solar cell producing country, with 31% of world solar cell produced. China PV module technology has also reaches or close to world advanced level.

The scale of China PV market is small and develops slowly. In 2008, the installation of PV was only 40MWp, only of 2% of the China domestic PV production and 1% of world PV market.

2.6 Impact, menace and opportunity of financial crisis on Chinese PV industry

1) Impact of financial crisis on the capital, manufacturer, and marketing of China PV industry

Due to the influences of finance crisis, financing of China PV enterprisers became difficult and short of capital. The first is that the finance agencies tighten the

credit policy; the second is that the market value of PV enterprisers falls down, with resulting from stock price declining. The incomes of the PV enterprise fell sharply for the decreasing of solar cell price in market. In addition, the majority of Chinese PV module is exported to Europe, with being settled by Euro currency, the devaluation of EURO in 2008 had brought about the enormous loss of economy, for the Chinese PV producers.

The two largest PV markets in the world, Germany and Spain, had released the unfavorable policies for PV market. New policy in Spain [24] notes that the scale of PV capacity subsidized is 500MWp, but the installation capacity in 2008 is 2.46GWp, which means about 80% PV market was cut off. New policy in Germany regulated that if PV installation exceeds over planned upper limited installation, the feed-in tariff will decrease by a rate of 9% with additional 1%. If the actual installation is smaller than that of lower limitation of capacity, decreasing rate of feed-in tariff will reduce down, based on 9%. The stipulated upper limitation is 1,500MWp, 1,700MWp, 1,900MWp, respectively in 2009, 2010 and 2011; the lower limitation is 1,000MWp, 1,100MWp and 1,200MWp, respectively in 2009, 2010 and 2011. Due to these policies guiding, PV demand increasing rate in international PV market will slow down accordingly.

The PV sales are greatly influenced by the financial crisis. Firstly, during the period of economy depression, investors become more cautious on large scaled PV power plants. Secondly, finance agencies control the scale of loaning, which is not in favor of the large-scale power plant construction. And the oil price goes down and energy supply situation slows down, which make the investment fund on renewable energy project lessen in short time. Above factors slowed down the expending of the PV market and also sped- up the dropping of PV module price.

The shrinking of PV market caused Chinese famous PV enterprisers to suspend the production and to lower down the future production capability. The weak and small companies of PV, with unstable market and small scale, lower technological level, and poor financing ability, are going into bankrupt.

If the situation of market shrinking can not be improved, lots of PV enterprisers will go into bankrupt, great amount of loan of PV companies will be in dangers. Partial employees in PV industry will lose job and PV industry will stop developing or be in recession.

2) Chinese PV industry facing re-construction

Due to large demand of PV modules, many Chinese enterprisers entered PV industry. But, for the impact of the financial crisis, the market demand shrink and PV related products price dropped. Finance agency tightened the policies of loaning; the

companies with weak capital strength have to be merged by the strong and large enterprises. As the Si material price come back to the rational level, those PV companies which mainly depend on buying and selling at a profit of poly-crystalline Si material are difficult to keep on surviving. With the impact of financial crisis, the PV industry became a market of buyer, but not seller market. Those PV companies with inferior situation, whose product is disqualified, management not well, technology and the capability of R&D is laggard and inferior, will have been washed out. Finally, those PV enterprises with stable market and advanced technology will be survived.

3) Financial crisis brings developing opportunities

The financial crisis brought the negative impact to the PV industry, but also the developing opportunities. PV industry is a rising industry with a considerable potential. Many developed countries take the PV industry into as one important action in dealing with the financial crisis. The policies had come out one after another to prompt the PV industry. The new US president, Obama, had elevated the industry of new energies, especially PV industry, to a height of national energy strategy and energy safety. It was stated that whoever master the renewable energy leads the 21st century. Green recovery plan was brought out, and the expectation of revitalizing US economy on the industry of renewable energy was laid on the renewable energy industry.

For the financial crisis lowered the price of PV module, the enterprises had to make effort in lowering the cost of the PV module in order to ensure the profit of the enterprise. The decreasing of the cost of the PV power is beneficial to the enlargement of the PV industry. It is hopeful for the PV power to be competitive with the conventional power generation.

The financial crisis promotes the reconstructing of the Chinese PV enterprises. The enterprises with strength are reserved, which lay the solid foundation for the healthy and orderly development of the PV industry.

2.7 Motivating force of international PV industry and market development

1) Pressure from energy and environment issue

From the global view, the contradiction between increasing demand on fossil energy resource and limited reserve of fossil energy is becoming more and more prominent. Over-use and abuse of fossil energy result in a good many of issues of environmental pollution and greenhouse effect.

In March of 2006, EU released green policy book of “the European strategy acquiring the sustainable, competitive, and safe energy” noted that energy pressure faced by EU includes growth of dependence on import energy, growing price of gas

and petroleum, and global warming, etc.

Currently, the serious imbalance does exist in the global energy production and consumption. Few developed countries consumed majority of energy, but with some big energy production countries, the energy consumption is far less than its energy production due to undeveloped industrial level.

As shown in Fig 2-13, petroleum importation of few developed countries account for almost half of world petroleum importation quantity. Due to the serious reliance of import energy and energy supply risk, energy security for developed countries is very evident [25].

Almost half countries of EU rely on import of energy. Currently, petroleum, natural gas and coal account for around 80% of total EU's energy consumption [26]. Energy import source mainly distributed in mid-east and Russia. However, unstable and turbulent political situation and terrorism is a big threat for energy supply.

Petroleum and natural gas reserve in Japan is almost zero, but Japan is the world third largest petroleum consuming country, second largest petroleum importer and first large liquid natural gas importer. Energy self-supplying ratio, including nuclear energy, is only 16% in Japan. Therefore, Japan faces severely energy security issue [27].

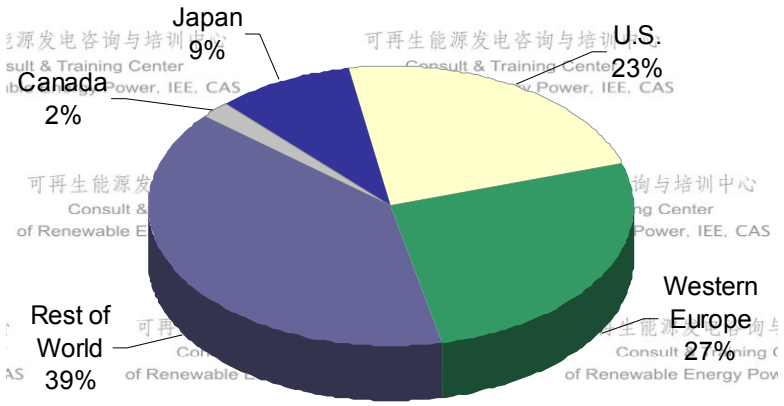


Fig 2-13 World import of crude oil by country in 2007

According to the statistics, per capita CO_2 emission of United States, Japan and Germany and other developed countries is much bigger than that of developing countries. Per capita CO_2 emission of United States is 19 tons, which is top one in the world and five times of the world average of 4.28 tons. Per capita CO_2 of Germany is two times of world average level. Per capita CO_2 emission average level of developed countries is much higher that that of average level of developing countries, see Fig 2-14[28].

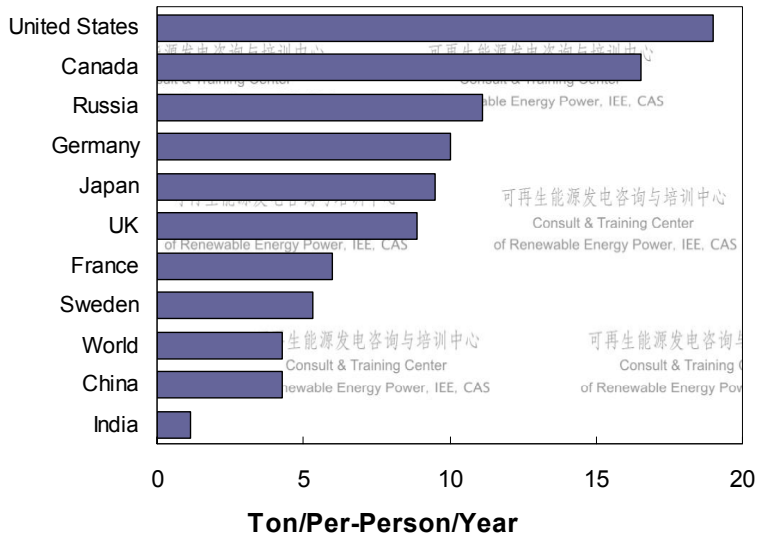


Fig 2-14 Annual per capita CO_2 emission by country in 2006

Therefore, CO_2 emission is a huge pressure what the developed countries are facing.

Actively promoting the renewable energy developing, including solar PV power, is an inevitable strategy measure for developed countries.

2) Striving for top position of future energy technology

Strategy significance of PV industry is realized world widely. In order to guarantee the leading position of the advanced PV utilization technology, many countries released one after another policy to support PV industry development.

The leading of the technology is one of important factors that the state economy is competitive. In order to assure the leading place of renewable energy field, developed countries has invested a lot on the renewable energy in advance, so as to control the frontal technology.

Germany is the country who depends on importing of energy. In order to promote the renewable energy development, Germany government enacted “Renewable Energy Law” in 2000. In Germany, PV industry experienced the explosive growth by implementing the “Feed in Tariff” of supporting policy. By the end of 2008, Germany ranked the first in PV installation with 5.6GWp installation capacity.

Japan is the earliest country which supports PV industry development by policy. In 1990, Japan modified the requirements and specifications of “Electric Law”, actively supports PV grid connection and application. By the end of 2008, accumulative installation of PV in Japan reached 2.1GWp. With the government powerful supporting, Japan PV production became the first in the world and PV industry was most competitive in the world. In 2009, Japan Ministry released “Low

Carbon Society Action", which notes that Japanese PV leadership in the world shall be reestablished and the PV power installation capacity will be increased greatly, the PV efficiency will be increased to around 40 percent in 2030 and per kWh cost down to 7 yen/kWh (converted to USD 0.07/kWh).

The new president, Obama, announced that the renewable energy development including PV power and PV industry will be the important measures to shake off the economy recession and to create jobs and renewable energy industry will become the strategy industry of occupying the high point of future development.

By exploiting the market of PV, the domestic PV industry technological ability and the competitiveness shall be improved, which further lays the foundation for the market expanding. With being driven by large scale market demand, PV enterprisers have groped for the new technology continuously, and optimized and updated the technologies, so as to take possession of leading position in PV field of the world. Therefore, rapidly starting-up of PV market is an important action that the developed countries tackle the issues of energy supply and technology competition from the view of strategy development.

3) Practical benefit of economy and society

The development of PV industry not only supplies clean energy and optimizes energy structure, but also brings huge economic and social benefit, mainly expression of increasing invest and employment.

Since 2000, accumulative investment in PV industry is over Euro 15 billion in Germany and the investment in PV system production chain is over Euro 3 billion. In 2007, PV industry created around 40000 jobs and sales income reached Euro 9 billion[29].

NREL[30] predicted that PV industry creates around 30000 jobs distributing in research, installation, and sales in United States. In 2007, American sale income of solar cell and PV module reached USD 1.72 billion.

With the breakout of financial crisis, many countries have taken PV industry development as an important measure to deal with the crisis, for that, the countries increase investment, create jobs and stimulate economy growth.

Japan government passed "Green New Deal", in which, including increasing solar electricity to 20 times, cutting off CO_2 emission, and creating jobs. Japan fiscal yearly budget in April, 2008 includes 20 billion yen for solar power subsidy. Since Jan, 2009, Japan began to resume all subsidies for solar cell industry. In the first quarter of 2009, Japan has granted 9 billion yen used for solar home solar energy application system, subsidy standard for home solar power system is 70 thousand yen/kWp, and

the goal in 2020 is 70% of new building to be mounted by solar PV panel.

The stimulus policy by US government is intended to invest USD 150 billion, which brings about five million jobs in the next ten years. In the new energy policy of USA, 10% of electricity shall be from renewable energy by 2012. On Sep, 2008, U.S. Senate passed an investment plan on renewable energy with a value of USD 18 billion, in which the tax credit policy on PV industry will be extended 2-6 years. In Jan.10, 2009, California government invested USD 3.2 billion, in order to promote "Million PV roofing plan", and to build PV power system of 300MWp in California by 2016.

EU has introduced renewable energy plan, and planned to expand Euro 30 billion investment and create around 350 thousands jobs.

In addition, France, South Korea, Greece and South East Asia countries also have paid more and more emphasis on PV industry development, and successively introduced the PV subsidy policy.

2.8 Significances of accelerating developing of Chinese PV market

1) Assuring the Chinese energy safety and environment sustainable development

According to above analysis, Chinese electricity gap will reach 597.6 TWh. For the resource and environment of solar PV power, it will be one of the important choices to fill up the gap. If the domestic PV market can not be started up in large scale in time, China will face more severe situation of power supply and demand in future. According to the forecast by international agencies, PV power generation will account for 20 percent of world electricity consumption in 2050, at that time, PV power will also account for 20% or so in the Chinese electrical power system. Based on Chinese energy & resource, environment situation, developing speed, industrial structure, it is the important actions inevitably for China energy sector to start-up the domestic PV market in large scale, so as to assure the energy safety and sustainable development, the lunching of the domestic PV market in large scale shall be implemented as soon as possible.

2) Assist China PV enterprisers to bail out of finance crisis

Because 98% of China PV products export to Europe and United States, Chinese PV is the one mostly influenced by financial crisis. The biggest problem what Chinese PV manufacturers are facing is the order decline. Accelerating China PV market will meet the demand of the strategic energy development and assist PV enterprisers to overcome the financial crisis. The "*Trial Measures for Solar PV building* Application Fund Management" recently released by MOF and the bidding of 10MWp PV power plant project organized by NEA greatly boost the market

confidence on renewable energy, the stock value of Chinese PV enterprisers listed in New York stock market increased by 30-50%. It clearly shows the tremendous role of national policies on PV enterprisers to overcome the financial crisis.

With the launching of the domestic PV market, PV enterprisers will be capable of resuming the producing; the ongoing research and expanding plan can be kept on, which is helpful for those enterprisers influenced by financial crisis and help to develop sustainably.

Launching Chinese PV market will boost the confidence of European and United States' market and accelerate the global renewable energy industry development. With reviewing the leaping development of Chinese PV industry, national "Brightness and SDDX Program" stimulated the establishment of Chinese PV industry. With being guided by around RMB 3 billion central governmental fund, Chinese PV industry experienced five years rapid development and became the world-first PV module producer and exporter in 2007. In 2007, Chinese PV module of 1717MWp accounted for 28.2% of the world production and the current year sales production value exceeded over RMB 88 billion; total asset reached RMB 120 billion inclusive of the in-construction asset of RMB 50 billion). PV industry became the high technology industry and the green economy growth point. It can be predicted that as long as the State properly open-up the domestic market, the Chinese PV industry will grow in difficulty period of time and gain rapid development. The market opening properly will not only increase the domestic demand, create jobs and contribute to the economic growth, but also occupy bigger share in the world PV market.

On the contrary, only if depending on its self to fight against the financial crisis, certain amount of medium and small PV enterprisers will go bankruptcy, except that many workers will be jobless, the loan of bank and financing agencies will be in serious risks and result in national property loss. Even worse, the flourishing Chinese PV industry would lose its good development opportunity and the priority hard-won.

3) Speed- up the Chinese PV industry to step into the field of Chinese electric power

With the economic and social development in China, the people's living level has been improved, which results in the gradually increasing of electricity demand. In order to meet the demand of electricity growing and to attain the sustainable development of electric power industry, PV power shall play more and more important role on the future's electric energy structure. According to the project team's forecast, nearly 20% of Chinese electricity will come from PV power.

The important condition that PV power can step into electric power system is that PV power is competitive with conventional power generation. At present, PV power cost is still much higher than that of conventional power generation, being without

competitive ability. Through domestic market expansion, large scale PV power application will help decreasing PV power cost. One report [31] of United States noted that the total installation capacity of PV power in Japan and Germany is much more than that in United States. For the scale effect, installation cost in Japan and Germany is lower than that in United States. In 2007, the average installation cost of solar home power system is USD 5.9/Wp and USD 6.6 /Wp in Japan and Germany; however, it was USD 7.9 /Wp in United States.

4) PV plays dominant role in the non-electrified area electric power construction

Implemented projects, such as SDDX, Silk Road Brightness Project, Sino-German Finance Cooperation Western China Village Program, by adopting PV power system, have supplied power for some residents, gained a good result and good resound from local residents reputably.

There are still around 10 million people who could not access electricity in remote areas in China, which seriously constrains the local economic and social development and the life quality of the residents from being improved. The remote non-electrified region is poor in traffic, backward in economy, far away from the grid, and in lot of which the conventional energy is not suitable to use. PV power has made a lot of contribution on the electric power supply in such kind of areas. PV power is not limited by hydro resource and other natural condition, solar energy is distributed everywhere on the planet. Moreover, non-electrified region is usually abundant in solar energy. PV can supply the economical and reliable electricity for the local residents and exert an important role on the non-electrified area electric power construction.

China is in superiority in PV off-grid power application and Chinese PV products and experiences can be used for the developing countries. On the earth have two billion people who are left without access to the electricity, which is also one of the reasons of poverty and lagging. United Nation has specified a special plan to support the PV application in developing countries. China shall open out the broad market with power.

5) Strengthen the nationality solidarity and border defense

The non-electrified households in China are mainly distributed in remote and poor minority regions and their living condition is urgent to be improved. PV has the unique advantage on electrification of distributed dwellers. Tibet is one region where is the most concentrated areas of no-electricity residents, where is rich in solar energy, therefore, PV power is very suitable in Tibet. Most of other minority regions in China are suitable to use PV power. The non-electrified area electrification can improve the life level of local people, help in promoting economy growth, removing

poverty, strengthening nationality solidarity and social stabilization in the border areas.

Many regions of border in China are far away from the grid and could not access the electricity. These regions are suitable to supply power by PV power system. In order to deepen the implementation of the action plan on enriching of border areas, promote the development of border areas, help enriching the areas, and defense the border, "the 11th 5-year Plan of Redeveloping and Enriching of Border Area", released by the China State Council, stated that in order to improve laggard electrical facility in border, the residents in border areas electricity supply issue can be address by using PV power and others.

6) Relief international pressure on environment issue

With respects of the environment issues that China is facing for several years, the expression mainly include: environment safety is the key content of the state security; the big total of pollutant emission has influence the global environment; conflicts with neighboring countries are elevating; rapid energy demand growth affects the world energy supply; and the environment issue has already become the constraints of the foreign trade [32].

President, Hu Jingtao, attended the Congress of Energy Security and Climate Change of the Economy Big Country in 2008, and pointed out that, based on the difference in terms of stages of development, levels of scientific and technological development, and national conditions, the effort on combating the climate change shall be made and guided in the principles of the common but distinguishing responsibilities, and shall play its role on something.

By integrating its economic and social development plan, China has made *The National Action Plan on Climate Change* to deal with the climate change. The very important and active mean of tackling the climate change is to harness the renewable energy, and renewable energy gradually substitute the fossil energy, so as to reduce the emission of greenhouse gases such as CO_2 to the greatest extent. PV power is a type of clean power generation technology. As one year operation of one kilowatt PV power system can reduce 16 kg nitrogen dioxide, 9 kg SO_2 and 2300kg CO_2 can be avoided [33]. If the 2GWp solar cell made in China in 2008 is installed domestically, annual emission reduction will be 32 thousand tons nitrogen dioxide, 18000 tons SO_2 and 4.6 million tons CO_2, which will play a very important role on improving of environment.

7) Enhance the capability of tracking public emergent events

In Sep, 2004, 4th plenary session of Chinese Communist party 16th Congress pointed out that the whole society alarming system shall be established, the

emergency response system of unified commanding, with complete functions, of flexible response, and of efficient operation mechanism shall be formulated, in order to improve the capability of guarantee public security and handling emergency affairs.

Electricity is the basic requirement for life and work. It is of significance for maintaining national security, social stability, and treasure and life security to build the comprehensive and effective mechanism of emergency power supply system and to deal with the electric power emergency affairs correctly, effectively, and quickly.

PV power has the feature with simplicity of installation and flexibility of scale. As the large grid is power off, PV power supply source can resume power supply to guarantee basic power supply for disaster rescue, emergency response, and the basic living needs. Therefore, PV power is used as the emergency power supply source in public emergency shelter and the public areas, as the disasters occur, PV power can supply the necessary electric power, so as to assure the power supply of the important institution and facilities such as communication, command and medical system, the capability of disaster prevention and mitigation can be improved, the loss, life, and finance property result from the disasters can be lessened to the lowest. During the period of post-disaster reconstructing, PV power system can keep on functioning.

8) Being in favor of pulling internal demand and adjusting industrial structure

Starting-up the domestic PV market has the positive impact on pulling internal demand, and can increase the sales quantity of products each stage of PV industry chain. According to *Chinese PV Development Report in 2007*, PV industry sales income was RMB 90.9 billion, with over 80,000 employees. The starting-up of Chinese domestic PV market will increase invest and the output of PV industry, in order to tackle the hit of financial crisis. The opening up of Chinese PV market will increase the investment on research, manufacturer, installation and training, which will play a positive role on promoting the internal demand and economic growth.

It will help optimize the energy supply system and lay the foundation for building the stable, economic, and clean energy supply system. PV industry is a new kind of energy industry, high technology industry, and the strategy industry leading the future. It is in favor of the upgrading of Chinese PV industry, the self-innovating, and the boosting of PV industry competitive capability in the world.

2.9 Summary

1. Necessity and urgency of accelerating of the Chinese PV Market

   1) The world energy structure is experiencing the third transformation, i.e. from fossil energy to renewable energy, so as to conduct the sustainable

development of society and environment. With the improving of technological level and dropping of the price, renewable energy application is rapidly growing and is substituting the fossil energy. Renewable energy is the only way to solve the energy supply issue in China and also to establish the substance foundation to fully realize the goal of establishing a well-off society in China. PV power is the one of the most important fields of renewable energy.

2) Chinese large energy demand grows fast and the energy structure is unreasonable. In 2008, net energy importing accounts for 10% of total energy consumption, energy supply shortage is being deepened. Though Chinese energy reserve is abundant; per capita energy possession quantity and per capita energy consumption is relatively little. Therefore, the energy demand growth space is huge. Coal is the major energy resource and half of coal is used in power generation, resulting in the serious environment pressure.

3) Coal-fired power dominated electric power energy structure is urgent to change. Thermal power accounts for 80.9% in electric power energy structure in China, which is higher than that of world average and the every developed country. PV power will play an irreplaceable role on optimizing of the electric power energy structure.

4) Launching the large-scaled Chinese PV market is in favors of lifting Chinese international impact force, and make contribution to the greenhouse gas emission reduction and improvement of environment and ecology.

5) It is recognized world widely that PV power will play an important role in the future electric power structure. United States, Japan, and Europe have set their own target of PV development. United State's target is to reach 25% of renewable energy power of total electricity in 2025. Japan's target is that PV power generation will be 40 times of the current PV Power generation in 2030. China has also set its PV development target, in which the total installation capacity is of 1.8 GW in 2020. The target set is rather low. Large scale PV market should be launched as soon as possible.

6) PV power has its unique role and special position on non-electrified area electric power construction. PV power has been used in "Brightness Project", "SDDX project" and Sino-foreign cooperation "Silk Road Brightness Project" to solve power supply issue. In the future, PV will still play an important role on the electric power construction in no-electricity areas.

7) There will be a huge electricity gap in the future in China. This study forecast that, total electricity demand is 6915TWh and the electricity demand gap will

be 597.6TWh in 2020 respectively. If 30 % of electricity gap is filled by PV power, which will need 120GWp PV power capacity; 50% of the electricity gap will need 190GWp, and 70% of the gap will be 270GWp. It is predicted electricity demand in 2050 will reach 10924.2 TWh, about 20% of the power will come from PV power.

8) Current electricity price could not reflect the real cost of coal-fired electricity. Cost of thermal power electricity should include electricity production cost and external cost of coal production and burning. After calculating, the real cost of thermal electricity is 0.563RMB/kWh. The cost of thermal electricity increment rate is between annual 5 percent with an error bound of 0.5 percent. Comprehensively considering growing external cost of coal-fired electricity and gradually declining PV cost, conventional electricity price and PV power will meet in the future. At that time, PV power is more competitive. China's plenty solar resource is one proper condition to develop PV power.

9) China has become first solar cell manufacturer with 32 percent world solar cell production. China has the breakthrough silicon technology and previous silicon shortage issue will be solved in recent one or two years. But, China PV market is still quite small, which is only equivalent to 2 percent of PV production.

10) Influenced by the financial crisis, international market shrinks, financial agencies tighten policy and stock price diving, PV enterprisers are difficult to finance. Due to the shrinking PV market, many PV enterprisers already stopped production and was facing bankruptcy, During the period of financial crisis PV enterprisers will reintegrated. In order to track the financial crisis, United States and other developed countries have taken PV industry as one stimulating measure, which creates a development opportunity for PV industry. It will stimulate the Chinese industry, market and research, and greatly improve China PV technology to open up scaled Chinese domestic PV market at present.

11) To help China hold the high position in future energy technology and strive active right of future energy supply, reducing conventional energy reliance would benefit China.

12) Assist PV power become a new economy growth point and increase more job opportunities, expand domestic demand, and optimize industry structure.

2. Significance of accelerating opening up Chinese domestic PV market

1) From strategic and global view, accelerating the opening up of Chinese domestic PV market is very important. It matters for Chinese and global

future energy security, energy and environment harmony development, and energy sustainability.

2) Accelerating the opening up of Chinese domestic PV market is in favor of slowing down the pressure of China and assist improving China status in the world and influence.

3) To assist Chinese PV enterprisers move out of finance crisis difficulty situation.

4) It is favor of cost drop of PV power and supporting PV power enter into electric power field earlier and improve current major coal-fired electric power energy structure

5) Large scale launching Chinese PV market will play an important role on improving capability of tackling the public emergent affairs.

6) Large scale launching Chinese PV market will promote PV power to become a new economy growth point, to increase jobs, to stimulate domestic demand and to optimize the industry structure.

References

[1] Editorial Board of Energy Encyclopedia, *Energy Encyclopedia*, Beijing: Encyclopedia Press. 1997

[2] National Bureau of Statistics of China. http://www.stats.gov.cn

[3] PRC State Council News Office. *Chinese Energy Conditions and Policies*. December, 2007.

[4] World Resource Institute.http://www.wri.org

[5] Mao Yushi, Real Cost of Coal, Coal Industry Press, Sep，2008.

[6] China Ministry of Environmental Protection, *Report on the State of the* Environment *in China 2007*.

[7] Chinese Association of Electric Power Enterprises. *Electrical Industry Statistics Express 2008.*

[8] Energy Information Administration Official Energy Statistics from the U.S. Government , http://www.eia.gov/electricity

[9] UD-led team sets solar cell record, joins DuPont on $100 million

project,http://www.udel.edu/PR/UDaily/2008/jul/solar072307.html

[10] European Renewable Energy Council .Renewable Energy Scenario to 2040. 2004

[11] Chen Yu, Wang Shaoyu, Li Yuanchu, *Framework and Strategy Plan of Europe Photovoltaic Development*, World Science & Technology Economy Outlook. Aug, 2007.

[12] People Website, http://world.people.com.cn/GB/1029/42354/7581601.html. Japanese Cabinet Meeting. Building Low Carbon Society Action Plan.

[13] Hu Xuehao. *Chinese electrical power demand development forecast*, Chinese Academy of Electrical Power. 2008.

[14] Zhao Xizheng, Scientific Developing and Advancing Jointly: Key note speech at Sino-Association of South East Asian Nations (=ASEAN) Electric Power Cooperation and Development Forum. Guangxi Electric Power. 2007(11)

[15] Liu Manping and Gui Lin, *Policies proposals and analysis on Chinese electricity supply and demand*, China Electric, 2004 (3).

[16] He Jiankun and Zhang Xiliang, *Strategies and Policies on Promoting Massive Renewable Energy Development,* Chinese Renewable Energy Development Strategy Workshop, Oct, 2005.

[17] Renewable energy source in figures national and international. Federal Ministry for the Environment，Nature Conservation and Nuclear Safety(BMU) Germany.2008

[18] Tang Jun, *Discussion on tracking measures and analysis of power generation* enterprisers *loss*, Pricing and Finance Supervisory Department, State Electricity Regulatory Commission (SERC).

[19] World Bank, *Economically, socially, and Environmentally Sustainable Coal Mining* Sector *in China*. Dec, 2009.

[20] Wang Sicheng, *Latest Development of PV Power*, 5th Seminar of China Solar Grade Silicon and PV Power, March,2009.

[21] Solarbuzz LCC. Annual World Solar Photovoltaic Industry Report，2009.3

[22] PV status report 2008. European Commission Joint Research Center Institute for energy，2008

[23] Solarbuzz LCC ,Annual world solar photovoltaic industry report(2008)

[24] Spanish Solar Growth is Good and Bad News for PV Industry, Semiconductor

international,http://www.semiconductor.net/article/CA6631126.html

[25] Organization of Petroleum Exporting Countries, Annual Statistical Bulletin 2007

[26] Paul Belkin. The European Union's Energy Challenges，2008.3

[27] Energy Information Administration Official Energy Statistics from the U. S. Government ,Background, http://www.eia.doe.gov/emeu/cabs/Japan/Background.html

[28] International Energy Agency ,Key World Energy Statistics 2008.

[29] Gerhard Stryi-Hipp. The Photovoltaic Market in Germany–Snapshot and Outlook. Germany Solar Industry Association. 2008

[30] Energy Information Administration Official Energy Statistics from the U. S. Government ,Solar Photovoltaic Cell/Module Manufacturing Activities, 2007, http://www.eia.doe.gov/cneaf/solar.renewables/page/solarreport/solarpv.html

[31] Ryan Wiser, Galen Barbose, Carla Peterman. Tracking the Sun, the Installed cost of Photovoltaics in the U.S. from 1998-2007. January,2009. http://eetd.lbl.gov/ea/emp/reports/lbnl-1516e.pdf

[32] Sina web, Ministry of Environmental Protection: *Increasing International Pressure on Environment Issue.* http://news.sina.com.cn/c/2006-06-12/061410129378.shtml

[33] U.S. Department of Energy, Energy efficient and Renewable Energy, Learning About PV: The Myths of Solar electricity, http://www1.eere.energy.gov/solar/myths.html#6

3. Feasibility Analysis on Chinese PV Market Development and the Acceleration

3.1 Profile of solar energy resource and the application potential in China

China has broad land and rich solar energy resources. According to the estimation, the annual solar irradiance on the land surface in China is about 1.47×10^7 billion kWh, which is equivalent to 4900 billion tons equivalent coal (TEC), with approximation of more than decades thousand times of the annual output of Three Gorges power project. The annual gross solar irradiance in China is from 933 to 2330 kWh/m^2, and the mean value is 1620 kWh/ m^2.

From the distribution of solar irradiance in China, the solar energy resource is very rich in Tibet, Qinghai, Xinjiang, South Inner Mongolia, Shannxi, north Shanxi, Hebei, Shandong, Liaoning, West Jilin, Middle and West Yunnan, Southeast Guangdong, Southeast Fujian, East and West Hainan, and Southwest Taiwan and so on.

The average altitude of Qing-Tibet Plateau is over 4000m with thin and clear sky, high transparence, low latitude, and long sunshine hours. The solar irradiance in Sichuan and Guizhou Provinces are the lowest, and Sichuan Basin is even lower, where is rainy, foggy, and of less shinny days.

The main characters of solar resource distribution in China: the high and low value centers are in the belt between N22° and N35°. Qing-Tibet Plateau is the high value center and Sichuan Basin is the low value center. The annual solar irradiance in the west is higher than that in the east; and the solar irradiance in the south is lower than that in the north, except in Tibet and Xinjiang autonomous regions. Plenty of fog and rain occur in the south of China; the distribution of solar energy in the belt between 30° to 40 °north latitude is different from the solar energy variation with the latitude, the solar energy does not decrease but increase with the increasing of the latitude.

According the amount of solar irradiance, the land can be divided into 5 sorts of areas in China.

1st area: Annual amount of sunshine is 3200 to 3300 hours; annual solar irradiance is 1860 to 2330 kWh/m^2, equivalent to the energy of 200 to 225 kg of standard coal. It includes Qing-Tibet Plateau, North Gansu, South Ningxia and South Xinjiang. They are the richest areas of solar energy, which are equal to the solar energy resource in India and North Pakistan. Especially the world-famous sun shinning city - Lasha of Tibet, with high altitude and high air transparence, in which

the annual solar irradiance value reaches 2330 kWh /m^2; next to Sahara desert, ranking the second in the world.

2nd area: annual amount of sunshine hours is 3000 to 3200; annual solar irradiance is 1630 to 1860 kWh per m^2, equivalent to the energy of 200 to 225 kg of standard coal. It includes Northwest Hebei, North Shanxi, South Inner Mongolia, South Ningxia, Middle Gansu, East Qinghai, Southeast Tibet, South Xinjiang, and so on. Rich solar energy is available in these areas.

3rd area: annual amount of sunshine hours is 2200 to 3000, annual solar irradiance is 1390 to 1630 kWh/m^2, equivalent to the energy of 170 to 200 kg of standard coal. It includes Sandong, Henan, Southeast Hebei, South Shanxi, North Xinjiang, Jilin, Liaoning, Yunnan, West Shanxi, East Gansu, South Guangdong, South Fujian, North Jiangsu, North Anhui, and so on.

4th area: annual amount of sunshine hours is 1400 to 2200, annual solar irradiance is 1160 to 1390 kWh/m^2, equivalent to the energy of 140 to 170 kg of standard coal. It includes the middle and lower Yangtse River, and parts of Fujian, Zhejiang and Guangdong, where are cloudy and rainy in spring and summer, but sunny in autumn and winter.

5th area: annual sunshine hours is 1000 to 1400, annual solar irradiance is 933 to 1160 kWh/m^2, equivalent to the energy of 115 to 140 kg of standard coal. It includes Sichuan and Guizhou provinces, where the solar energy is the lowest in China.

In China, the 1st, 2nd and 3rd category areas, with over 2000 annual sunshine hours and 1620 kWh/m^2 of solar irradiance, are rich or very rich in solar energy resource, such land area is very broad, occupying over 2/3 of the total area of China; the utilization condition of solar energy is very favorable. Although the solar energy resource in 4th and 5th category area is not ideal, there is still certain utilization value of solar energy.

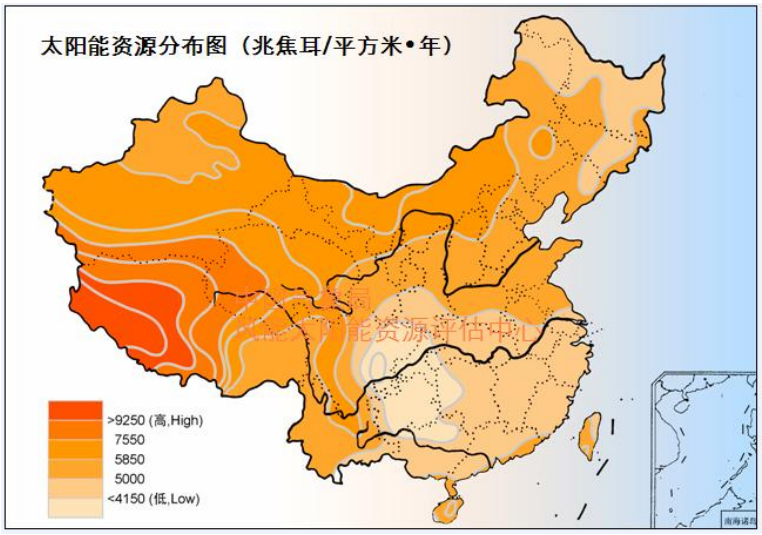


Fig. 3-1 Solar Energy Distribution Map of China

Solar Energy Reserves in Mainland of China

The gross theoretical value of solar energy resource in China is 1.47×10^7 billion kWh yearly, the theoretical gross reserves of all provinces are showed in the Tab 3-1 (the sort order is by magnitude).

Tab 3-1 the theoretical reserve of solar energy resource in the China (order by magnitude)

No.	Province	Theoretical Reserves	Acreage	No.	Province	Theoretical Reserves	Acreage
		10^5 billion kWh per year	10^4 km^2			10^5 billion kWh per year	10^4 km^2
1	Xinjiang	27.06	165.0	16	Hubei	2.23	18.6
2	Tibet	23.60	122.8	17	Shandong	2.19	15.7
3	Inner mongolia	17.75	118.3	18	Henan	2.18	16.7
4	Qinghai	13.66	72.2	19	Liaoning	2.06	14.8
5	Sichuan	7.36	48.7	20	Jiangxi	2.04	16.7
6	Gansu	6.70	45.4	21	Guizhou	1.89	17.6
7	Heilongjiang	5.97	45.4	22	Anhui	1.69	14.0
8	Yunnan	5.77	39.4	23	Jiangsu	1.65	10.3
9	Hebei	2.88	18.8	24	Fujian	1.56	12.1
10	Guangxi	2.84	23.6	25	Zhejiang	1.28	10.2
11	Shanxi	2.60	20.6	26	Ningxia	1.09	5.2
12	Jilin	2.48	18.7	27	Hainan	0.47	3.4
13	Hunan	2.47	21.2	28	Beijing	0.26	1.7
14	Guangdong	2.40	17.8	29	Tianjin	0.16	1.2
15	Shannxi	2.30	15.6	30	Shanghai	0.07	0.6

From the point of the economical condition, the east region is developed in economy with concentrated population; the most PV industries are located in the east economy-developed provinces, the PV industry are much paid attentions by the local governments, such as Jiangsu, Hebei, Shanghai, and other provinces, the industrial electric power load is very heavy, the per capita electric power consumption is higher than that in west of China. However, in the west area, the local economy is backward, and the capability of investment of local governments and the local people is limited. But the PV industry and PV power project look promising as well. The local governments are very enthusiastic for large scale PV grid-connected power projects, for the purpose of promote the local economy developing; some companies with abundant capital invest in the PV industry chains actively. In Xinjiang, Qinghai, Ninxia, and Inner Mongolia, several poly-crystalline Si projects were launched, with the upsurge of investment of poly-crystalline Si projects.

In terms of solar energy resources, it is very rich in Xinjiang, Tibet, Qinghai, Gansu Hexi Gallery, West Inner Mongolia, and other regions, where the abundant land resources has not been utilized or with the very little utilizing value of the land; in these area it is very suitable to build the large-scale grid connected PV power plants and solar thermal power systems. In most municipalities and cities, solar energy resource is very rich as well; it is also very promising to build the city PV power systems in the west.

PV industry layout shall consider the balance between west and east, in order to realize mutual supplement by exerting resources advantages of the west, east and middle regions; the following factors shall be considered: economical and social development level, electric load distribution, natural resource, such as Si material and the grade of silicon, solar energy, land area, roof area, electric power system distribution, and so on. From the point of view of industrial chains, the macro control and planning shall be performed.

3.2 Chinese RE developing plans, laws, and the relevant rules and policies

1) *Renewable Energy Promotion Law of PRC*

On February 28, 2005, at the 14th Meeting of the Standing Committee of the 9th NPC, *the Renewable Energy Promotion Law of PRC* was passed, in the Law is stipulated that the policies of preferential feed-to-grid of RE power, being full purchasing by grid corporation, favorable pricing, and social apportioning, etc.,

2) *Electric Power Law of PRC*

Article 3: The electric power industry shall fit the needs of national economy and social development and develop in advance appropriately. The State encourages and guides legal investment in the development of power sources and the establishment

of power generation enterprises by domestic and overseas economic organizations or individuals. Investment in the power industry shall implement the principle of "whoever invests, who benefits."

Article 47：The State adopts preferential policies for rural electrification, and provides special support to rural power construction in minority nationality areas, remote areas, and production and construction corps areas.

Article 48：The State encourages and supports rural areas to utilize energy resources to develop rural electric power sources and to increase the rural power supply.

3) *Energy Conservation Law of the PRC*

Article 4: The State encourages the development and utilization of new and renewable energy.

Article 11: The various level governments shall arrange energy conservation funds in the funds for capital construction and technological transformation to be used in support of rational utilization of energy and development of new energy resources and renewable energy resources.

Article 38: Governments shall follow the guidelines of “adapting to the local conditions, multi-energy complementing, comprehensively utilizing and seeking benefits” strengthen energy construction in the rural areas, develop and exploit the new and renewable energy, incl. solar energy.

4) NDRC enacted “*Medium and Long-Term Development Plan for Renewable Energy in China*”, (NDRC Energy [2007] No. 2174), on Aug 31, 2007,

It states that: by 2010, China will aim to raise the share of renewable energy in total primary energy consumption to 10 percent. By 2020, it will aim to raise this share to 15 percent. Among which the solar power plan is:

By 2010, the total capacity of solar power in China will be 300 MW. By 2020, it will be 1.8 GW. The key tasks of development will be as follows:

(1) The basic living electricity will be supplied for the residents by solar home systems and small-scale PV power stations in the no-electricity area, such as Tibet, Qinghai, Inner Mongolia, Xinjiang, Ningxia, Gansu, Yunnan, and so on. About 100 MW of solar PV will be installed to supply electricity to 1 million households of herders and farmers in remote areas. By 2010, then, the accumulated capacity of solar PV for remote rural areas will be 150 MW. By 2020, it will be 300 MW.

(2) At the same time, China will aim to develop the grid-connected BIPV in economically developed large and mid-sized modernized cities. BIPV will firstly be

applied in public buildings and then extended to the other building, and use PV lighting in roads, parks, and stations. The demonstration project should be implemented in Beijing, Shanghai, Jiangsu, Guangdong, and Shandong in 11th Five-Year Period. By 2010, 1000 roof PV projects will be finished with capacity of 50 MWp; and by 2020, 20000 roof PV projects will be performed with total capacity of 1 GWp.

(3) Finally, China will aim to build large solar PV and solar thermal power plants. In 11th Five-Year Period, large-scale grid-connected pilot PV power plants will be built in Dunhuang of Gansu and Lhasa or Ali in Tibet, and solar thermal power stations will be built in deserts, Gobi, or unused land in Inner Mongolia, Gansu and Xinjiang. By 2010, the grid-connected solar power capacity will be 20 MW (large-scale, grid-connected solar PV power stations) and 50 MW (solar thermal power), respectively. By 2020, the corresponding figures will be 200 MW for grid-connected solar PV power stations and 200 MW for solar thermal power stations.

In addition, there is a large potential for solar PV application in communications, meteorology, long distance pipelines, railways, highways, etc. The application of solar PV technologies in these commercial areas will be 30 MWp by 2010 and 100 MWp by 2020.

5) NDRC enacted "*Renewable Energy Development 11th 5-year Plan*", (NDRC Energy [2008] No. 610), on Mar 3, 2008,

In the "*Renewable Energy Development 11th 5-year Plan*", it was stated that:

The target is that: By 2010, the total capacity of solar power in China will be 300 MWp, the demonstration projects of MWp-level solar energy generation and the 10MW level solar thermal power generation will be carried out, in order to promote the development of supporting industry system, and to lay the technological foundation of large scale application of solar energy generation.

Construction project distribution and key projects

No-electricity Area Electric Power Construction

In accordance with local conditions, the basic living electricity for the residents will be resolved by solar home (PV) systems and small-scale PV power plants in the no-electricity area, such as Tibet, Qinghai, Inner Mongolia, Xinjiang, and other remote area, with 100MWp PV power system.

Urban PV power Program

The PV power application program shall be carried out in large and medium-sized cities, where the solar energy resource is rich; PV power systems shall be installed on the roof of new high grade villas and the municipal landmarks

buildings; PV lighting is favorable in residential areas with close management, tourism scenery zones, traffic and city lighting. By 2010, the total capacity of solar power in city will be 50 MWp.

PV Demonstration Plant

The large-scale grid-connected PV power plants will be built in the areas with rich solar energy resource, such as Inner Mongolia, Ningxia, Gansu, Qinghai, Xinjiang, Tibet and so on, the total capacity will reach 50MWp.

6) *White Book of 2007 on Chinese Energy Situation and Policies*

In the White Book, it was specified that: renewable energy will be developed powerfully, and developing renewable energy is in priority. The harnessing and utilization of renewable energy resources play significant roles in increasing energy supply, improving the energy structure, and promoting the environmental protection and it is also a strategic choice for China to solve the contradiction between energy supply and demand to achieve sustainable development.

7) *NDRC*, *Trial Management Measures of RE Power Pricing and Expenses Apportioning*, June 1, 2009

8) *NDRC, Notification on "Temporary Measures on RE Tariff Add-in Revenue Adjustment and Allocation*", NDRC Pricing [2007] No.44

9) *NDRC*, Notification on "*Management Regulation on RE Power*", Jan 5, 2006

10)*NDRC*, Notification on "*Temporary Measures on RE Developing Special Fund*", May *30*, 2006.

11)*NDRC*, Notification on "*Rural Non-electrified Area Electric Power Construction Issues*", NDRC Energy [2005] No. 1367.

12)*SERC* No. 25 Decree, *Supervision Measures on Grid Corps fully Purchase RE Electricity*, *being* put into force on Sep 1, 2007

13)*NDRC* and SERC, Notification on "*RE Tariff Subsidy and the Portfolio Trading Plans in Oct, 2007-Jun, 2008*", Nov.20, 2008. In this plan, the items and amount of RE tariff subsidy, trading of tariff add-in quota, accounts settlement and inspection requirement from October 2007 to June 2008 had been determined. The government pricing administration and the regional and municipal electric power regulatory authorities should strengthen the inspection of RE tariff subsidy's collection, quota trading, settlement of electricity charges and subsidy; the activities that violate the regulations should be corrected and punished seriously, so as to ensure the RE tariff subsidy put into effect in full and on time.

14)*MOF*, Finance & Constructing [2009] No.128, the Implementing Guideline on

Boosting –up of Solar PV Power Integration with Building.

15)*MOF*, Finance & Constructing [2009] No.129, Notification on "*Measures on Financing Subsidy Fund of Solar PV Power Integration with Building*".

3.3 PV Power Technologies Status and the Application

The matured and commercialized solar cell technologies include crystalline Si solar cell, thin film Si cell, GaAs thin film cell, CdTe thin film cell, CuInSe thin film cell, etc.

Crystalline Si solar cell is the mainstream of solar cell, including the pulling mono-crystalline solar cell and casting poly-crystalline solar cell, which occupy 80% of solar cell market, with being used in solar home system (SHS), PV power station, and BIPV.

The crystalline Si industry and technology status will be narrated in chapter 4 as well.

In recent years, the world PV industry increases at the rate of the more than 30% per year, which leads to the shortage bottleneck of raw material in the upper stream of PV industry. Although the conversion efficiency of commercialized a-Si thin film solar cell (6-8%) is lower than that of mono-crystalline Si (15-17%), the a-Si thin film solar cell uses the silane and float glass, and other material, which can breakthrough the bottleneck of crystalline Si material competition.

The Si-based thin film cell occupies 10-12% of market, mainly of amorphous Si; the on-developing a/μ crystalline Si laminated solar cell is mainly used in the toy, small calculator, BIPV, and desert PV power stations.

The Si-based thin film (a-Si (mono-, dual-, and tri-junction a/μ crystalline Si) suppliers is listed in the appendix 10.1.

The Solar Power Dept. of Applied Materials Inc. predicted that the lower cost advantage counteracts the shortcomings of lower efficiency, the demand increasing rate for the thin solar cell will be the two times of the traditional Si solar cell.

Comparing with the crystalline Si solar cell, the consumed Si quantity of the Si-based thin film cell is only 1% of the former or so, Si-based thin film cell cost is decreased from USD2.5/Wp to USD 1.2/Wp. In addition, the Si-based thin film cell can be integrated with the roof of buildings, and wall materials, not only can be grid connected to generate power, but save constructing material and beatify the environment.

In 2008, the First Solar Co. Ltd has reduced his production cost of CdTe cell to less than US$1/Wp, the conversion efficiency reaches 11% or so. In 2007-2008, thin

film cell is the hottest pot in global PV industry; there are the new thin film solar cell projects being put into operation or the news released constantly, the few suppliers of equipment manufacturing in the world received a mass of orders from more and more new investors. Beside First Solar, other companies have invested on thin film industry, such as Sharp, Q-CELL and Schott. Taiwan has more than 10 thin film projects. It is attracting more and more capital and attention in mainland corporations, such as A-Si Top Tuori New Energy Co., Ltd, and Xinao Group Co., Ltd. It is a main impellent power that the advantage of power generation and lower cost of thin film cell which will reduce the cost of PV power generation. Although the crystalline silicon cell is the mainstream of PV cell in a shot time; in the long run, the thin film cell will compare favorably with traditional energy.

CdTe solar cell cost is lower, whose application occupies 1-2% of total solar cell market, which is mainly used in the desert power station. At present, the technology has not been fixed and stabilized. In the world, only one company, First Solar, can produce the CdTe solar cell in large scale.

CuInSe thin film cell, which has lower cost and higher theoretical efficiency, is a promising solar cell. However the producing technology of CuInSe thin film cell is not mature, although there are several pilot experimental producing lines and small scale companies, the real large scale of producing does not occur so far.

The civil application market of GaAs thin film cell is very small, far less than 1%. GaAs thin film cell's efficiency is high, but and the cost is high as well. GaAs thin film cell is mainly used in space craft and concentrated cell. In the early of 1980s, it was used in space craft, especially in the power supply system of small satellite. The market of GaAs thin film cell is increasing more and more in space power supply; it is more then 90% now.

The list of CdTe and CIGS manufactory are in appendix 10.2 and 10.3.

3.4 Lessons and Experience from Chinese PV Power Technology Application

Chinese PV power has been applied mainly in 1) no-electricity area electric power construction; 2) mobile phone communication station power supply, etc.

On August 2007, NDRC enacted "*Mid and Long-Term Development Plan for Renewable Energy*", and "*Renewable Energy Development 11th 5-year Plan "*on May 2008, which set the RE development target of China further. According the 11th 5-yeay development plan of renewable energy, by 2010, the total capacity of solar power will reach 300 MWp in China, and 1800MWp by 2020.

After SDDX, the domestic PV market in China is under a condition of slowly developing, annual installation capacity is 5 to 20MWp. But the PV industry is

developing rapidly under the drive of international PV market. In 2007 the output of solar cell and PV module are 1200MWp and 1800MWp respectively, but only 20MWp PV power system was installed in China, majority PV modules were exported.

The Chinese central government has paid great attentions to the non-electricity area electric power construction project in the rural areas. Besides the grid extension and small hydropower, a series of projects of no-electricity area electric power construction by PV power were implemented, such as “Brightening Engineering Pilot Program”, “Tibet Ali District Brightening Program”, SDDX and so on; SDDX project is the largest PV power project of solving the electricity supply by PV power in no-electricity area in the world with the biggest investing strength. The international cooperation PV power projects have been performed such as “Silk Road Brightening Engineering Program”, “Sino- Germany Financing Cooperation West Solar Power Program”, and Japanese NEDO Aid Program, etc.

In China, the issues of the off-grid PV power project management, O/M, financing are summarized as follows:

1. Property right issue

The issue of the property right is the precondition of project management and daily maintenances, and is the necessary condition that the projects exert sustainable impact. So far, there is no any official document to definite the property right of village PV projects.

2. Issues of operation and management

The O/M after project completion is the key to the PV power sustainability and long term functioning in remote rural areas. In terms of the village PV power system, except few projects (such as KFW program), there is no the official documents stating clearly that the qualified institutions can operate and manage the existing PV power plants. Most plants of SDDX project are charged by local government, but are maintained and served by the project executive agencies (PEA) or the system integrators. Without the specific PEA and an effective O/M organization, the project can not be accepted and transferred, the legal and efficient O/M can not be done; If the responsibility and obligation are not clarified, and the PEA can not received the tariff subsidy; the PV power plants are facing the huge menace in the normal operation.

3. Project inspection and accepting, checking and supervising

In the no-electricity area electric power construction project, except KFW project, any other project has not be checked and accepted in legal senses, which causes that the follow-up work could not be done.

The ultimate target of the no-electricity area electric power construction project is "**to offer a long term and reliable power supply service for the consumers**". The PV power system must be inspected and accepted after project completion as a staggered symbol of being put into use, the long term and reliable and high quality O/M can be guaranteed if only the PV power system is inspected and accepted by PEA, the project supervision must be done thoroughly all the life span of the project. But currently, there is no efficient supervision mechanism for existing projects generally.

It is obvious that, the top priority of no-electricity area electric power construction project are: establishing corresponding organization, drafting efficient rules, checking and accepting existing plants, strengthening projects supervision, establishing long-term supervision mechanism, ensuring the project supervision done thoroughly all the life span of the project, and ensuring long term and reliable power supply service.

4. Experience of the quality control and guaranty of no-electricity area electric power construction project

1) Quality control in whole process

The quality controls in whole process of off-grid PV power program include three aspects: quality control of project management, quality control of construction process, and quality control of O/M and power service.

(1) In quality control of project management, the project proposing, approval, construction, management, operation and O/M are considered as a integrated whole; the quality control for this whole process includes 1) standardizing the procedure and process of project management, 2) establishing the quality control system, 3) establishing checking and supervising organization, 4) drafting rules and regulation, technology and quality standard and requirement for guaranteeing projects quality, and so on.

(2) The quality control of project construction process includes 1) quality assurance for equipments（PV module, battery, electrical devices, etc.）and 2) quality control for constriction engineering (PV power station, plant houses, village mini-grid). Details include the items of site-selection, site-verification, selection and demonstration on the technical scheme, project bidding, construction, supervision, and acceptance, etc.

(3) The goals of quality control of O/M are to assure the project to exert the integrated benefit in economy, politics and society, and to provide long-term and reliable power supply service for the consumers. It includes 1) service after construction completion, 2) quality of electricity, 3) equipments maintenance, 4) Tariff

collection, and 5) use regulation system implementation. The premise conditions are the establishing of the management models and administrating organization for operation management.

2) The experience of quality guarantee and control

In Chinese non-electrified remote areas, beside grid extension, the off-grid PV power system is suitable to be adoptive for the solution to the basic living electricity issue. In order to assure the quality of project implementation and perpetual functioning, not only the quality of power generating facilities and power supply system need to be guaranteed, but also a series of regulations in management level need to be actually implemented, so as to assure the high quality of construction and installation of the off-grid PV power system, and long-term reliable operation and satisfied power service after project being accepted and transferred.

3) Ultimate target of "non-electricity area electric power construction program"—power supply service

In the no-electricity area electric power construction program, the principle of "**the long term and reliable power supply service for the consumers**" shall be stressed and highlighted, not only the installation and the construction of the facilities and system, but also the O/ M after project completion. The cost of project investment, O/M cost, and the cost of component replacement must be considered as a whole. The short periodic construction and installation of generation devices is just a part of the whole process, but the long-term power service will last for 10 to 20 years. Therefore a complete system of PV power generation and power supply shall be established.

3.5 Domestic PV market developing potential analysis

In the next few decades, the PV power will be applied in the following fields in China:

1. Non-electricity area electric power construction

Due to the historical and geographical reasons, so far there are about 10 million residents in remote area without being accessed of electricity, most of which is in the west minority nationality area in border area. Because of the far distance to the grid and scattered *dwelling*, henceforth, the possibility of grid extension is very little. These areas with very rich solar energy resource, where the grid is difficult to reach, are main PV power markets.

In more than 400 inhabited islands, the economy and reliability of off-grid PV power system has its priority than that of using diesel power.

The solution to the problem of power supply in the remote area residents is

embodying the concepts of the “Three Representatives” concretely and is an action of building the harmonious society, with a far-reaching importance. And it will do favor of west development in China; it will be of great importance on the nationality solidarity, frontier defense solidification, and on the promotion on the remote area economy development.

The *Mid and Long Term Renewable Energy Development Plan* states that: In rural areas, renewable energy applications will be developed to resolve the issues of daily energy use for vast rural population in China, to improve rural production and living conditions, and to protect the ecological environment. Harnessing of renewable energy will effectively raise rural incomes and increase the development of social and economic development in rural areas. The priority for development is to supply power to the non-electrified rural areas. The details are that, for those areas where it is not economic to extend the power grid, by making best use of the local natural resources, by using small hydro, solar, and wind, as well as other renewable energies, the basic electricity demand of people being deprived of power supply can be met. In the areas with rich resources of small hydropower, top priority will be given to develop small hydropower (including pico hydropower), and about one million households can be supplied by hydropower. In those areas lacking of small hydropower resources, by means of (depending on local resources) small off-grid solar PV power stations and wind-PV hybrid power stations, as well as small household wind- PV home systems, and wind-PV home systems, about one families can be electrified. By 2015, all the non-electrified people electricity use issue can be solved by grid extension and renewable energy off-grid power systems.

The advantages of PV power, such as simple structure, small volume, easy operating & maintenance, cleanness, safety, noiselessness, high reliability, long life ban, have irreplaceable function in power supply project in remote areas. From 1980s, the PV system had been applied in remote pasturing area. So far, the total installation capability is 100MWp. In 2002 to 2004, 720 solar power plants had been constructed (total 19.6MWp) in SDDX program implemented by NDRC, which resolved the issues of electricity supply in all town governments seated villages in China. PV power system will play a leading role in the follow-up project of power supply to non-electrified rural areas. Therefore, PV power system applied in remote areas will be a main growth point in the development of PV market in the near future.

At present, there are 10 million residents without being electrified, mainly distributed in Tibet, Xinjiang, Qinghai, Yunnan, Sichan, and other remote areas. Based on per capita 200 kWh, the annual electricity demand is 0.2 billion kWh. If off-grid PV power system is considered, and calculating with 800 equivalent hours per year, the total power capacity will reach 2.5 GWp. It is a considerable scale PV market.

2. Distributed PV Power system

Distributed PV power sources are the grid connected system installed at the end of the grid by consumers and the special use of stand-alone power supply system. The “Roof Plan” and the “Building Integrated PV Project”, currently implemented in Japan, Germany, USA, and other European countries, belong to the distributed PV power system. Today the developed countries adopt the incentive policies, attract the private investment, which is becoming a way of solving the energy and environment issues, the impact is very prominent.

Distributed PV power system can solve the electric power and energy problems in large scale, reduce emission, enforce the safety of power supply; without any issues of electricity transmission. If being applied widely, the dependence of user on the few large power supply points can be alleviated; and the grid can be avoided to be disabled, as national grid is destroyed in few large power supply points due to the war or some catastrophes. The distributed PV power system will be of special significance for the safety of power supply.

PV power has its vast market potential in urban streets and residential area illumination. The technology is mature and reliable and easy to manage and operate. According to the situation of China, the PV illumination in urban street and residential areas will be the main field of PV application program, sponsored by the government.

Although there is a big difference between the housing condition in China and the developed countries, it is a kind of positive and feasible measures to encourage the individuals and organizations to build the distributed PV power system, by using the policy mechanism. In central cities, distributed PV power supply shall be actively popularized. With regard to the public buildings (such as school, hospital, government, and factory, and enterprises buildings roof) and the top grade buildings, government shall enact policies to regulate the installation of the PV on roofs and walls, in order to exert the pilot impacts.

The advantages of distributed PV power supply:

- Can be connected to the grid, especially in the regions with large electric power load in summer.
- Can reduce the electricity loss in power transmission and dispatching.
- Can be used as an emergency power system, and resume the power supply quickly the disaster occurred.
- Can be widely used in cities, use of BIPV can save the cost of land acquisition in cities.

With a roughly estimating, Chinese roof area of total building may be about 40

billion sq meters; with being supposed that only 1% roof area is covered by PV panels, the energy of 60TWh can be generated each year.

As a kind of emergency power supply, PV power has its unique advantages; the application potential will be very huge.

3. Grid-connected PV power plant in Open field

The large scale grid connected PV power system is the inevitable path for the PV large scale application. It is proved that the technology is feasible and practical. MWp level grid-connected PV power plants have been constructed in developed countries, such as Germany, American, Spain, Portugal, etc; and some large-scale plants are constructed even in India, Philippine and some countries in Africa. The domestic large scale PV power plants are under planning.

In China there is total of 850,000 km^2 deserted land, which is mainly distributed in the northwest with rich solar energy resource; the annual solar irradiance energy is 1600 to 2300 kWh/m^2. The area belongs to the area with very rich solar energy in the world. In terms of the MW level PV power without the requirement of water resource, the northwest area is very prospective for the PV power development in large scale, The deserts in west China, Such as oasis rim of Hexi Gallery in Gansu, rim area of Xinjiang Takelamagan Desert, North of Shannxi and Shanxi, Eerdoudi of Inner Mongolia, and so on, are close to the electric power lines and the load centers, where can be proposed as the preferential starting areas for the large scale grid connected PV power project. And with the improvement of the electric power transmission and electric power storage technologies, these broad deserted areas can be developed as the forthcoming electric power centers and bases.

If the 3% of desert land of China be used for grid-connected PV power system as the base of strategy development, based on 50MWp/km^2, the potential capacity of PV power system is 1620 GWp. See the following table:

Tab 3-2 Potential capacity of PV power in China

Province	Solar Resource	Desert Acreage 10^4 km^2	Potential Capacity 10^4 kW（3% desert）	Electricity Transmission Distance
Inner Mongolia	1st ,2nd area	25.10	37,000	BTT/300~1,200km
Ningxia	1st ,2nd area	0.77	1,110	BTT/800~1,000 km
Hebei	2nd, 3rd area	0.55	800	BTT/200~300 km
Gansu	1st area	5.30	7,950	BTT/1,400~1,800 km
Qinghai	1st ,2nd area	4.28	6,400	ZRD/1,800~2,500 km
Xinjiang	1st ,2nd area	45.83	68,000	BTT/2,500~3,000 km ZRD/2,600~3,500 km
Total		81.83	121,260	

Ps: BTT is Beijing-Tianjin-Tangshan
ZRD is Zhujiang River Delta.

The condition of super high voltage electricity transmission must be considered for large-scale PV power system in open field. Propose that the national energy administration shall coordinate State Grid Corp to make the construction plan of electricity transmission channel, which can create conditions for the development of solar power generation in large scale.

Tibet is the richest area in solar resource. But it is early to apply PV power for electricity outputting and transmitting, because of its high altitude, bad construction condition and being far away from the load center. But PV power generation can play an impotent role for resolve its own electricity demand.

Chinese vast desert and the deserted land can be used as the precious basins of energy concentrating, which guarantees the multiplication of the Chinese nationality and the sustainable development. From the view of the national energy strategy and safety, the large scale MWp level PV power project shall be putting into practice as early as possible, among which the large scale MWp level PV power is matured, which needs supporting national policies, and push it into the operation of commercialization.

4. Other commercialized application of PV power

Other commercial application of PV refers to the application without being subsidized by government, such as standalone communication station power supply, pipeline cathode protection, and small commodity power supply etc. In China, the main commercial use of PV is in standalone communication station power supply which is 70 % of the total. The domestic PV market has been promoted by technology advancement, market exploitation, especially the rapid development of international market and commercial application. In 2010, Chinese commercial application of PV may be up to the 30-50 MWp installation accumulatively; the annual production may be up to 500 MWp hopefully.

3.6 Summary

1. Besides the 4th and 5th sort of areas in China, the 2/3 of the total land in China has good conditions for PV power generation; there is great development potential and market demand in the future.
2. The state has adopted a series of law, especially the Renewable Energy Law of PRC, which laid the foundations of law for PV power. The supporting policy enacted by NDRC, SERC and MOF provide policy guarantee for the large scale development of solar PV power generation.
3. In the long run, due to the technology advancement and market development,

per kWh cost will decrease; it is a general trend that the PV power will become major alternative energy gradually.

4. The market prospect of PV industry is very board, including: ① no-electricity area electric power construction; ② distributed PV power supply; ③ Grid-connected PV power plant in open field.
5. At present, the technology of PV power generation is mature; the major barrier is high cost per kWh. The multiple factors impeding the decline of PV power per kWh cost include solar resources, technical level, quality of installation and maintenance, intension of policy support and investment mode, etc.
6. The technology the crystalline silicon solar cell is mature. In the future, with the fast development of thin film PV technology, maybe a half PV market will be occupied by thin film solar cells, due to the lower cost.
7. The current main problems are that how make the PV power generation commercialized and the cost decreased thru technology advancement, market operation, incentives policy, and other control measures.
8. The experience of off-grid PV power project: ① the ownership of the project must be specified; ② the models of operation, maintenance and management must be defined; ③ the process whole process quality control and guarantee must be strengthened.
9. If off-grid PV power system is considered to meet the demand of people without accessing the power, basing on per capita 200 kWh and 800 operation hours per year, the total capacity will reach to 2.5GWp. This is a PV market with considerable scale.
10. If the 3% of desert land in China be used for grid-connected PV power as the base of strategy development, based on 50MWp/ km^2 installed, the potential capacity of PV power system is 1620 GWp.

References

1. *Electricity Law of the PRC*, Dec 28, 1995.
2. *Renewable Energy Law of PRC*, Feb 28, 2005.
3. *Energy Conservation Law of the PRC*, Apr 4, 2008.
4. *Chinese Energy Situation and Policies*, 2007.

5. NDRC, 2007年8月31日 NDRC Energy [2007] No. 2174. *Renewable Energy Medium & long Term Development Plan*. Aug 31, 2007

6. NDRC Energy [2008] No 610. *Renewable Energy 11th Five-Year Development Plan*, Mar 3, 2008

7. NDRC, *Trial Management Measures of RE Power Pricing and Expenses Apportioning*, Jun 1, 2006

8. NDRC, Pricing [2007] No. 44, *Temporary Measures on RE Tariff Add-in Revenue and the Allocating*, Jan 1, 2006

9. NDRC, *Notice on the Management Regulation on RE Power*, Jan 5, 2006

10. NDRC, *Notification on "Temporary Measures on RE Developing Special Fund",* May 30, 2006.

11. NDRC, Energy [2007] No. 421. Notice Concerning the Improvement of the Rural Grids and Electric Power Construction in No-electricity Areas in 11th 5-year plan, Feb 26, 2007

12. NDRC, Energy [2005] No.1367. *Notice Concerning the Issues of Electric Power Construction in No-electricity Areas*, Jul 11, 2005

13. SERC No. 25 Decree, *Supervision Measures on that Grid Corp fully Purchase RE Electricity*, Sep 1, 2007

14. MOF, Finance & Constructing [2009] 128, *the Implementing Guideline on Boosting –up of Solar PV Power Integration with Building*, Feb 23, 2009

15. MOF, Finance & Constructing [2009] 129, Notification on "*Measures on Financing Subsidy Fund of Solar PV Power Integration with Building*", Feb 23, 2009

16. SERC, *Regulations of Electric Power Business Permit,* Dec 1, 2005

17. *NDRC*/GEF/WB/REDP. *China Photovoltaic (PV) Industry Development Report (2004-2005)*, May, 2005

18. NDRC/GEF/WB/REDP, *China Photovoltaic (PV) Industry Development Report (2006-2007)*, May, 2008

19. CREIA, *China Solar PV Development Report (2007)*, Sep, 2009.

20. *IEE*, CAS, *China PV Development 11th 5-year Plan* (Proposed draft), 2005.

4. Analysis on the Cost, Price and Technology Progress of PV Power in China

4.1 Characteristics of present PV industry chain in China

1. Composition of PV industry chain

PV industry chain is composed of manufacturing of high-purity Si, ingot/wafer, solar cell, PV module, and PV power system, as shown in the Fig 4-1.

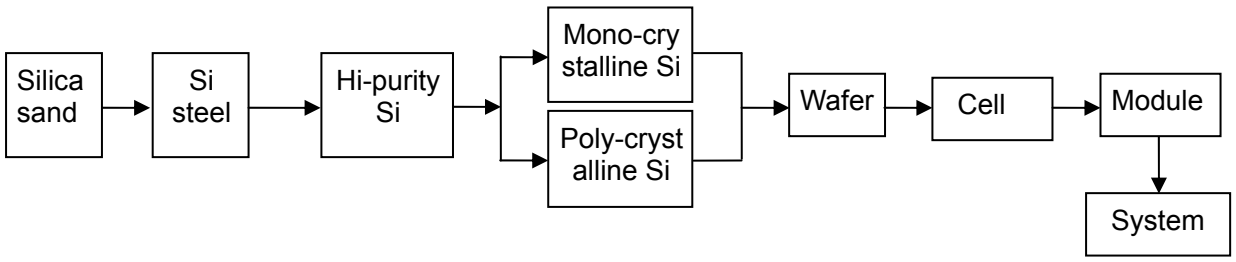


Fig 4-1 Composition of PV industry chain

2. Characteristics of present PV industry chain in China

1) Chinese PV industry chain is becoming integrated

With six years rapidly developing, the original situation that the crystalline silicon was confined for large scale c-Si PV module production has been changed, the current situation is that the crystalline silicon fabrication has achieved breakthroughs, ingot/wafer and cell companies developed rapidly, many new PV module enterprises emerged. The PV industry Chain from poly-crystalline Si material to PV products is becoming integrated gradually. Based on the statistics, in 2008, annual production output of poly-crystalline silicon was 4,500 tons, there were eight poly-crystalline Si enterprises being put into production; and there were more than 60 wafer/ingot producers, with annual production output of about 20,000 tons of wafer; 60 solar cell manufacturers with the production output of cell of over 2,000 MWp; PV module companies number is more than 330, the production of PV module was 3GWp. The production quantity in each stage of PV industry is shown in Fig 4-2. Jiangsu province PV industry and products processing base has become the largest scale in China; also, PV industry has been paid a great attention by the local governments to the PV industry developing powerfully in Zhejiang, Shanghai, Jiangxi, Hebei, Sichuan, Henan, Chongqing, Qinghai and other provinces, which have create the favorable policy environment and conditions for the further developing of PV industry.

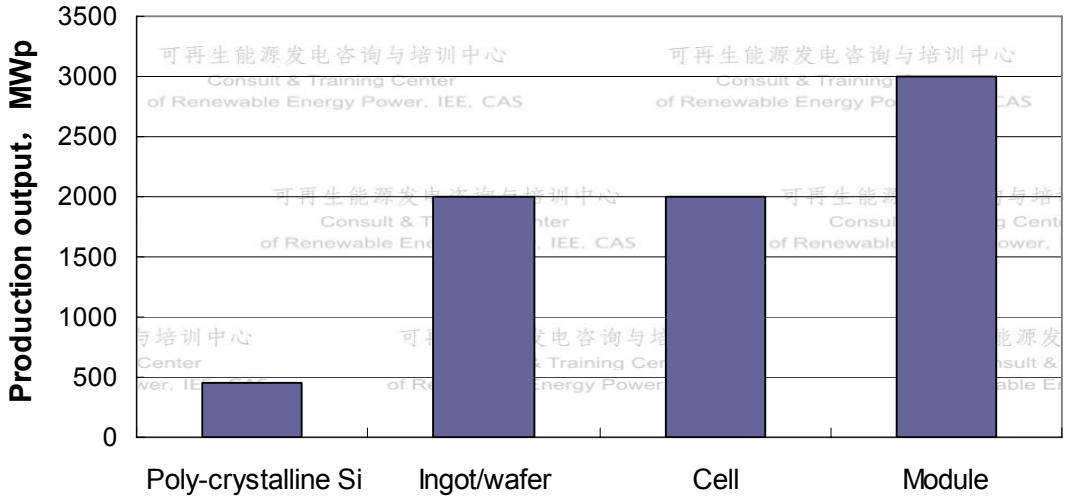


Fig 4-2 Chinese PV production in each stage in 2008
(Note: poly-crystalline Si consumption is calculated with 10g/Wp solar cell)

2) Dramatic development of PV industry in China

In 2007, China became the top of the solar cell producer and exporter, with annual production of 1,088MWp, representing 27.2% of global production. That year's sale was over RMB 88 billion. PV industry has been a new growth point of high technology industry and green economy. In the past four years, the sales of PV industry increased continually, and the employment number increased correspondingly. In 2005, the sale was RMB 12.8 billion; the number of employees was 13,800. In 2007, the sale was up to RMB 88 billion; the number of employees increased to 82,800. In 2008, the sale of PV industry in China was up to RMB 200 billion estimated. The growth trend is shown in Fig 4-3.

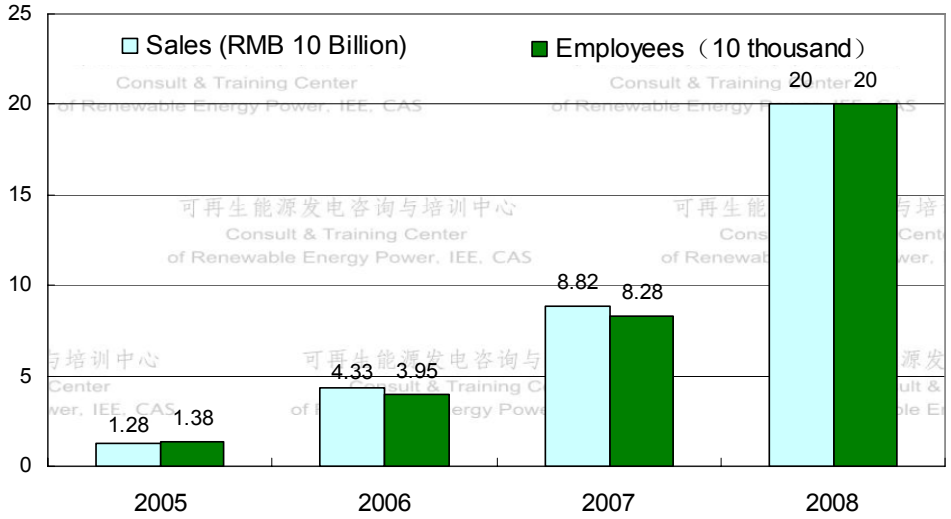


Fig 4-3 Sales and employment of PV industry in China in 2005-2008

In 2008, there are more than 500 enterprises and R&D institutes engaged in PV industry. Some companies showed themselves and went into the foreign Stock Exchange, such as Suntech Power, Ying Solar, LDK, Trina, Sunergy, and JA Solar, which was paid great attentions by the international financial sector, energy sector

and industry of PV. For example, the annual production capacity of Suntech increased from 10MWp in 2002 to 1,000 MWp in 2008. Suntech with the shipment of 497.5MWp, with sales of RMB 13 billion, has ranked the third in the world PV top list. In 2008, Yingli Solar with annual production 281.5MWp has ranked the sixth in the world PV top list. Chinese PV industry has been on the way of “specialization, integration, and large-scale”.

Tab 4-1 China PV companies listed on the foreign stock exchange

	Company’s name	IPO time
1	Suntech Power	Dec. 2005，New York Stock Exchange(NYSE)
2	Zhejiang ReneSola	Jul. 2007, NYSE
3	Canadian Solar	Nov. 2006, NYSE
4	Solarfun	Dec. 2006, NYSE
5	Trinasolar	Dec. 2006, NYSE
6	JA Solar	Dec.2006, NYSE
7	China Sunergy	Feb. 2007, NYSE
8	Ying Solar	Apr. 2007, NYSE
9	Jetion	Jul. 2007, London Stock Exchange
10	LDK Solar	Aug. 2007, NYSE
11	CNPV	Aug. 2008, NYSE Euronext (ALCNP)

3) PV market depends on overseas in excess

By the stimulus of China “SDDX Program” and the rising demand of international market, China PV industry developed dramatically since 2003, the highest growth rate was 300% in 2003-2008. Production output of PV module was 3.0GWp in 2008, while the domestic PV installation was 40MWp, which means 98% production was to be exported. It can be seen that Chinese PV market depends on overseas severely. Due to the global financial crisis, Chinese PV industry was impacted severely, one PV company had a net loss of USD 21 million in its 2008 Q3 report; another one had a net loss of USD 65.9 million[1]. The global demand of PV market declines. Since Oct 2008, in terms of the listed companies of Yingli, China Sunergy, and so on, except the few well-operating PV companies, majority companies‘ production decreased by 30-60%, the exporting by 50-80%, partial enterprises have been in deficiency. Chinese PV industry must be affected by the fluctuation of overseas market, because Chinese PV production sale depends on the oversea market with over 98% share. Under the circumstance, the malfunctions and the serious results of over-relying on the foreign PV markets have come out evidently.

4) Vast investment on PV industry

Benefited from the long-term development of PV industry, PV industry investment boomed over the past years. According to the statistics, so far nearly 50 companies, under construction, expansion or under planned construction, are

building the poly-crystalline silicon manufacturing lines, based on the “Modified Siemens Art & Craft”, the total scale is more than 100,000 tons, and the investment is more than RMB100 billion, among which the 1st batch‘s scale exceeds over 40000 tons, with over RMB 40 billion investment. By the 3rd quarter, the formed production capacity was already 20,000 tons, with the fixed asset investment of RMB 20 billion. 1GWp production capacity of ingot/wafer, cell, and module need RMB 10 billion. At present, 5GWp production capacities have formed, with RMB 50 billion investment on the fixed assets. 3GMWp is under construction, with which the RMB 30 billion fixed asset investment is being formed. The producers of wafer/ ingot, cell, and module have expanded one by one. The formed and in-constructing production capacity and investment of PV manufacturing industry are shown in Tab 4-2 and Fig 4-4.

Tab 4-2 Production capacity and investment of PV manufacturing

Production stage	The formed		In construction	
	Production capacity	Investment (0.1 billion)	Production capacity	Investment (0.1 billion)
Poly-crystalline silicon	20000 tons	200	20000 tons	200
ingot/wafer	5000MWp	240	3000MWp	144
cell	5000MWp	240	3000MWp	144
module	5000MWp	20	3000MWp	12
Total		700		500

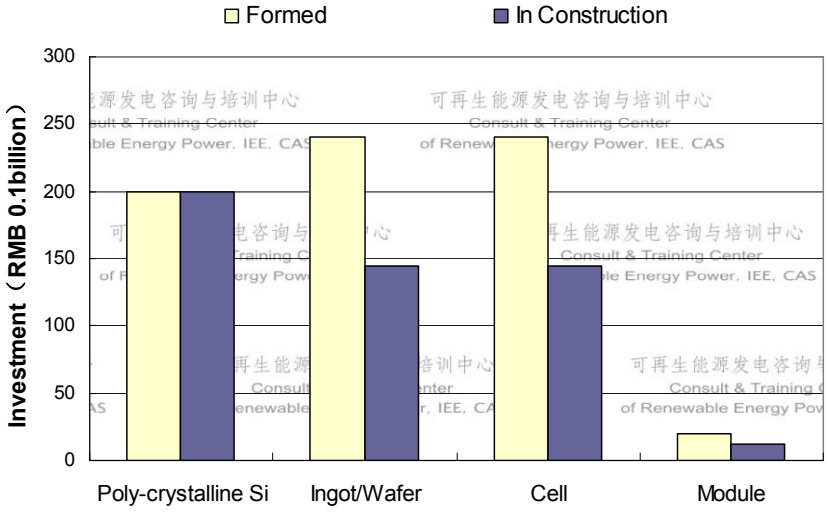


Fig 4-4 Chinese PV industry investment in each stage

5) The geographical distribution unbalance of the PV industry in China

At present, the uneven geographical distribution of PV industry in China: most production capacity is on the east. Tab 4-3 shows the analysis and statistics on the main PV companies in China in 2007, which include 6 companies with poly-crystalline silicon production of more than 20 tons; 24 companies with ingot/wafer production of more than 40 tons; 20 enterprises with cell production of

more than 5MWp; 30 enterprises with PV module production of more than 7MWp. The six companies of poly-crystalline silicon are located in four provinces: Jiangsu, Shanghai, Sichuan, Henan, with a total production of 1130 tons. The 19 silicon ingot/wafer producers are in the five provinces of Jiangsu, Hebei, Jiangxi, Zhejiang and Shanghai, with a production of 9840 tons totally which accounts for 83.3% of the total. The sixteen enterprises of solar cell are in the four provinces of Jiangsu, Hebei, Zhejiang and Shanghai, with a production of 1,025.7MWp which accounts for 94.3% of the total production in China. The 22 enterprises of PV module are distributed in the five provinces of Jiangsu, Hebei, Zhejiang, Shanghai, Guangdong, with production 1,423MWp which accounts for 82.9% of the total production. It's obvious that PV companies mainly distribute in the eastern coastal provinces of Jiangsu, Shanghai, Jiangxi, Hebei etc, while few are in the west, Fig 4-5 shows Chinese PV industry's distribution.

Tab 4-3 Data of PV production and the company in 2007

Province	Poly-crystalline silicon		Ingot/wafer		Solar cell		PV module	
	Number of Co.	Pro.(ton)	Number of Co.	Pro.(ton)	Number of Co.	Pro.(ton)	Number of Co.	Pro.(ton)
Jiangsu	2	205	6	2,700	8	667	12	821
Hebei			2	2,700	2	255.7	2	280
Guangdong					2	15	2	130
Shanghai	1	20	4	650	4	50	4	97
Zhejiang			6	1,490	2	53	2	95
Yunnan					1	7	1	30
Tianjin			1	40			1	25
Beijing			1	150	1	7	2	19
Hubei							1	15
Shanxi							1	15
Fujian							1	10
Shandong							1	10
Jiangxi			1	2,300				
Liaoning			1	900				
Inner Mongolia			1	100				
Xinjiang			1	60				
Henan	1	520						
Sichuan	2	385						
Total	6	1,130	24	11,090	20	1,054.7	30	1,547

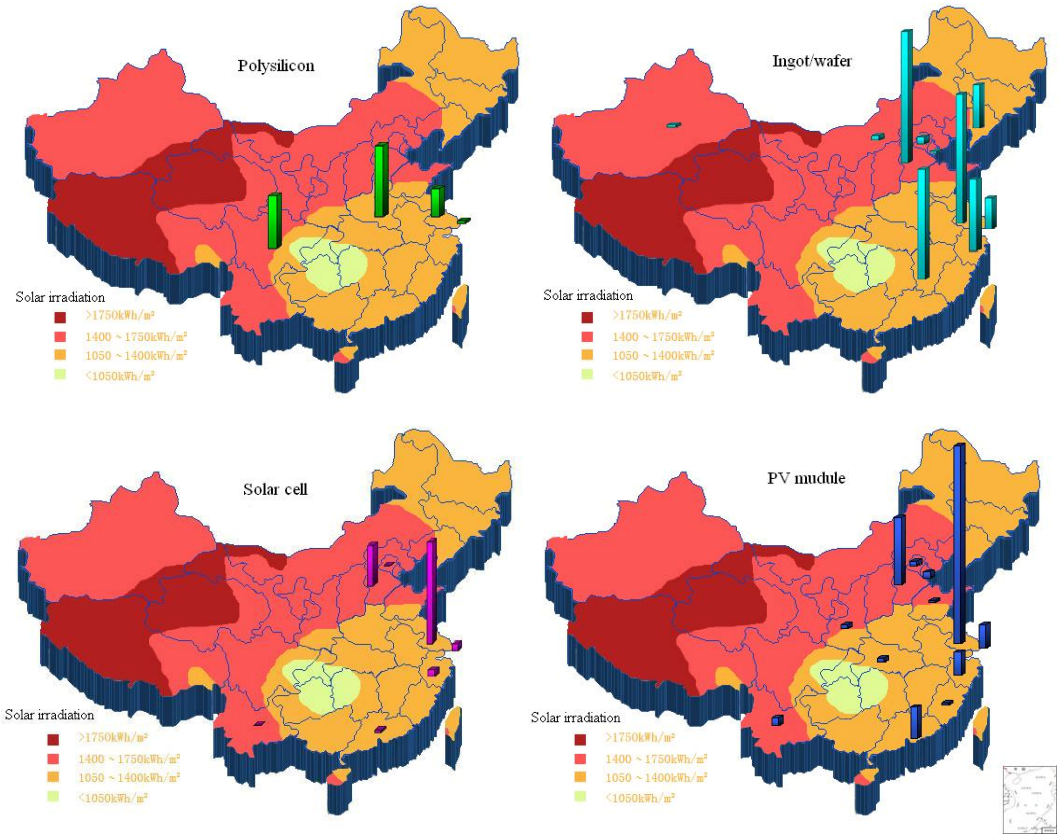


Fig 4-5 2007 Chinese PV industry distribution

In 2008, some changes have taken place in the distribution of PV industry, especially the poly-crystalline silicon production extended to the Midwest regions of China gradually. According to the statistics, by the end of Jan 2009, there had been 17 poly-crystalline silicon enterprises being put into operation, and the formed production capacity was 21,000 tons/year; more than 10 poly-crystalline silicon companies were being in construction and the production capacity was 26,000 tons /year. As shown in Fig 4-6, the production capacity of poly-crystalline silicon in Jiangsu, Henan, Sichuan has formed 4,400, 4,000, 3,800 tons/year respectively, there are certain formed production capacity in Inner Mongolia, Qinghai, Ningxia, Hunan, Hubei etc. The production capacity of poly-crystalline silicon is tremendous in future.

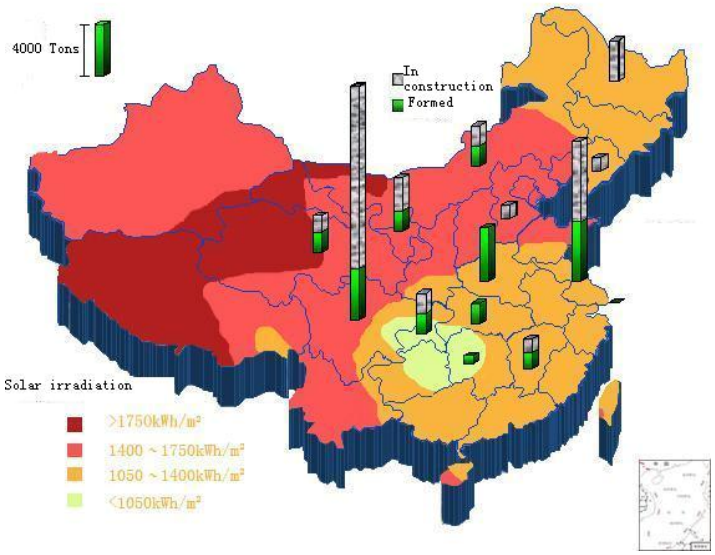


Fig 4-6 2008 Poly-crystalline Si industry profile

At present, the most companies engaged in ingot/wafer, solar cell, PV module encapsulation are distributed in the east coastal provinces, such as Jiangsu, Zhejiang, Shanghai, Jiangxi, Hebei etc. Comparing with east coastal areas, the mid-west provinces have the predominant condition, such as lower price of industry-using electricity, lower labor cost, cheaper land cost, the rich solar energy resources, and the broad PV application market.

The regional distribution balance shall be concerned in the development of PV industry. The central government shall make the relative policies to guide the investment, layout a certain scale of PV industry properly in mid-west provinces by utilizing the advantages of resource, cost, market. The new built and expanded project of manufacturing line of ingot/wafer, solar cell, and PV module in Inner Mongolia, Xinjiang, Qinghai, etc, shall be conducted by integrating with the development of poly-crystalline silicon project in local and the large scaled PV power project. In this way, the layout of PV industry in China can be equalized reasonably; meanwhile, the economic and social development can be promoted in the mid-west.

6) Chinese PV industry facing the big ventures

Global PV demand has a sharp shrink due to the financial crisis; the global PV market will come into the stage of market of buyers for the surplus of PV production in 2009. More than 98% of PV products in China were exported. Chinese PV exporting has been hit seriously. Due to the connections between upstream and downstream of the PV industry chain, the sharp declines in demand have affected on the every stage of the industry chain, such as ingot casting, wafer-cutting, and the one of poly-crystalline silicon. At present, some small and medium-sized PV enterprises have stopped producing. Once producing is cut by more than 30%, the enterprise won't get any profit; if with reducing 50% of production, it will be in loss; it

will go bankrupt on the condition of more than 70% reduction. If the utilization rate of Chinese PV production capacity in 2009 declines to 40%, majority PV enterprises will be in trouble. Therefore, the whole photovoltaic industry chain of China is facing a great risk.

China PV industry has built a good industrial foundation through many years' efforts, and has become a relatively leading industry with independent intellectual property. It is possible for Chinese PV industry to reach the scale of RMB 1000 billion production values around 2010. Once the whole industry chain gets loss and the finance chain breaks, all the efforts of Chinese PV industry will be lost, and the industry may face the risk of recession.

If Chinese PV industry was destroyed seriously, the foundation of Chinese PV industry will be damaged a lot, which maybe make RMB 100 billion fixed assets idle, the production value will be reduced by 200 billion, and more than 100,000 people employment may be in problem.

Chinese PV industry are suffering from the most serious hit past ten years, PV industry urgently suggest that the government will start up the domestic PV market with an installed capacity of 500MWp or more per year to support PV industry, and help the PV industry out of the difficulties. The PV enterprises are making efforts in promoting the technologies progress and reduce the cost, it is expected that the cost of PV power will be reduced to RMB 1.0 /kWh or less in 2012.

4.2 Status of PV industry chain in China

1. Poly-crystalline silicon material

Until today of PV power technology development, crystalline Si solar cell is the mainstream of commercialized solar cell all along, more than 98% of solar cells is made from the high-purity poly-crystalline silicon in the world market. As the most basic material of cell fabrication, poly-crystalline silicon purification is one of the most important manufacturing stages of solar cell.

"Modified Siemens Arts and Crafts- $SiHCl_3$ reduction" is still the main production process of high-purity poly-crystalline silicon (accounting for about 80% of global production). The energy consumption of high-purity poly-crystalline silicon is 125-170 kWh/kg.

Before 2006, poly-crystalline silicon production was controlled by the ten manufacturers in the developed countries, whose production in 2001-2006 is shown in Tab 4-4[2]. With the big demand of PV market, poly-crystalline silicon industry develops rapidly. Except that the original manufacturers speed up the expansion, many new enterprises invest on the building of new poly-crystalline silicon producing lines actively.

. Tab 4-4 ten big poly-crystalline Si suppliers' production in 2001-2006

Unit: Ton

Company	2001	2002	2003	2004	2005	2006
Hemlock(USA)	5300	5100	5300	7000	7700	10000
Tokuyama(Japan)	3500	3600	4000	4800	5600	6000
Wacker(Germany)	3700	4000	4200	4600	5600	6600
Mitsubishi(USA)	875	1065	1170	1210	1250	1250
Mitsubishi(Jap)	1050	1300	1300	1400	1600	1600
Sumitomo(Japan)	550	700	700	700	800	900
MEMC(USA)	800	1500	1500	2200	2200	2600
MEMC(Italian)	1000	1000	1000	1000	1000	1000
Asimi(USA)	2800	2050	2100	2400	3000	6500
SGS(Germany)		150	1900	2200	2700	(REC)
Total	19575	20465	23170	27510	31450	36450

With the pulling of demand of foreign PV market, Chinese poly-crystalline silicon industry has made rapid technological progress. Via introducing, digesting, and absorbing of the modified Siemens method, and continual innovating in the production process of poly-crystalline silicon, Chinese poly-crystalline silicon purification technology has reached the international advanced level. For example, Xuzhou Zhongneng Si Co., Ltd, by adopting the hydrogen chloride technology, and high-volume de-oxidization furnace with high deposition rate, and effective tail gas recovery technology, and so on, realized the entire close-loop recycling process and zero discharge. The energy consumption has reduced to 127kWh/kg, close to the international top level. Its product of the first batch is the solar-grade; the every indexes of the second batch can meet the standard of electronic grade, the poly-crystalline silicon purification technology has gained breakthrough and the great progress.

In 2006, Chinese total production of poly-crystalline silicon was only 290 tons, among which including Luoyang Zhonggui 185 tons, Ermei Semiconductor 105 tons. In 2007, the great progress in poly-crystalline silicon purification technology was made; the expansion of production capacity is very rapid. Luoyang Zhonggui's production capacity has expanded from 300 tons to 1,000 tons, and the production in 2007 was up to 520 tons; Sichuan Xinguang 1260 tons poly-crystalline silicon production line started to operate, with an production of 230 tons in the current year; 1500 tons production line was built in Xuzhou Zhongneng, and the same year production was 150 tons; Wuxi Zhongcai produced 55 tons poly-crystalline silicon, based on the 300 tons production line. The output of production of poly-crystalline Si exceeded over 4,500 tons in 2008. Production data is shown in Tab 4-5. Fig 4-6 shows the development of China's poly-crystalline silicon production over the past years, from which the rapidly developing of poly-crystalline silicon can be seen.

Tab 4-3 Production output and capacity of poly-crystalline silicon 2005-2007

Unit: Ton

Company	2005		2006		2007	
	Capacity	Pro.	Capacity	Pro.	Capacity	Pro.
Sichuan Ermei	100	80	100	105	200	155
Luoyang Zhonggui	300	—	300	185	1,000	520
Sichuan Xinguang	—	—	—	—	1,260	230
Xuzhou Zhongneng	—	—	—	—	1,500	150
Wuxi Zhongcai	—	—	—	—	300	55
Shanghai Lengguang					50	20
Total	400	80	400	290	4,310	1,130

Fig 4-7 Poly-crystalline silicon production output of China in 2000-2008

2. C-Si ingot/ wafer

Ingot/wafer is the second stage of PV industry chain. With the drive of PV market in recent years, the crystalline Si ingot/ wafer manufacturing has been developed rapidly. So far, more than 60 manufacturers involved in ingot/wafer, the ingot/wafer production has reached 20,000 tons in 2008.

Chinese mono-crystalline silicon ingot manufacturing technology has reached the international advanced level, and energy consumption of the advanced enterprises is 62kWh/kg. Over the past few years, China made a rapid growth in mono-crystalline ingot production. Tab 4-6 shows the main manufacturers of solar grade mono-crystalline ingots and its production. In 2005, 2006 and 2007, the total production of mono-crystalline ingot was 2216, 4550 and 8070 tons respectively. At the end of 2007, the amount of mono-crystalline silicon furnaces is about 2400, the annual production capacity is about 14,400 tons/year.

Tab 4-6 Production output of solar grade mono-crystalline silicon

Unit：Ton

No.	Company	2005	2006	2007
		Pro.	Pro.	Pro.
1	Ningjin Jinglong	1126	1250	1500
2	Zhejiang Yuhui	300	750	1100
3	Jinzhou Xinri	400	750	900
4	Yangzhong Huantai	—	350	900
5	Changzhou Tianhe	—	300	680
6	Yangzhou Shunda	100	250	500
7	Shanghai Kamudanke	—	30	450
8	Changzhou Yijing	80	200	300
9	Jiangyin Hairun	—	40	200
10	Langfang	—	100	150
11	Zhejiang Jiashan	—	—	120
12	Neimeng Hushi	—	—	100
13	Zhejiang Kaihua	—	70	100
14	Shanghai Hejing	—	30	80
15	Shanghai Songjiang	—	30	70
16	Xin Sunoasis	—	—	60
17	Huzhou Xinyuantai	—	—	50
18	Shanghai Jiujing	—	20	50
19	Tianjin Huanou	—	20	40
	Rest	210	360	710
	Total	2216	4550 *	8070

The poly-crystalline silicon ingot production technology is more complicated than that of mono-crystalline silicon. Fewer poly-crystalline silicon manufacturers exists and with lower production. The energy consumption for polycrystalline silicon ingot is 33-55kWh/kg. Data of manufacturers and production is shown in Tab 4-7. In 2005, 2006 and 2007, the production of poly-crystalline silicon ingot is 300, 1120, 3740 tons respectively. At the end of 2007, the number of poly-crystalline silicon casting furnaces was 230, and the production capacity was about 7000 tons/year.

Tab 4-7 Production output of poly-C Si Unit：Ton

Company	2005	2006	2007
LDK	—	450	2300
Yingli	260	550	1200
Changzhou Tianhe	—	—	120
Shaoxing Jinggong	—	80	80
Nibo Jingyuan	40	40	40
Total	300	1120	3740

Silicon slicing is the key technology of wafer production. The quality and the scale of slicing of directly affect the subsequent producing of the total industry chain. Si Multi-wire sawing is an advanced method for slicing silicon. Internal circle cutting has been gradually replaced by this kind of technology. At present, many enterprises adopt the multi-wire sawing, the thickness of wafer is decreased to 180-200 mm; the energy consumption is 220-300kWh/kWp. By using the multi-wire sawing, 400 kg silicon ingot can be cut to 13,000 pieces of wafer.

3. solar cell producing

1) C-Si cell production

C-Si cell is made of silicon wafer through the technology of diffused junction, based on the mono-crystalline and mono-crystalline Si wafer. The commercial c-Si cells have a similar producing process, including damage layer removal, textured surface production, electrode printing, sintering and so on.

With the strong drive of the world PV market, Chinese PV industry maintained rapid growth in 2007 and 2008. Despite the constraints of raw materials, many new companies have involved in PV industry over the past two years. According to statistics, by the end of 2008, the number of the enterprises engaged in cell production was more than 60, with a solar cell production capacity over 5,000 MWp, based on the number of the in-line equipment. Tab 4-8 lists the main cell manufacturers and its production in 2006, 2007. With respects of the cell production, Suntech's production was 157.5MWp in 2006 and 327MWp in 2007, accounting for 35.9% and 30.1% of that year Chinese production respectively. The production of other companies and the sort order are shown in Tab 4-10. Solar cell production in China was 438MWp in 2006 and 1088MWp in 2007, in which the crystalline Si was 426MWp in 2006 and 1059.7 MWp in 2007 [2]. Solar cell production in 2008 had reached 2GWp.

Tab 4-8 Production output of solar cells Unit：MWp

No.	Company	2006		2007	
		Pro.	Sequence	Pro.	Sequence
1	Suntech Power	157.5	1	327.0	1
2	Yingli	35.0	3	142.5	2
3	JA Solar	25.0	5	113.2	3
5	Solarfun	25.0	5	88.0	4
4	Sunergy	54.0	2	78.0	5
6	Canadian Solar	25.0	5	55.0	6
7	Ningbo Solar	30.0	4	45.0	7
8	Trina Solar	7.0	—	37.0	8
9	Jiangyin Junxin	14.0	7	35.0	9
10	Changzhou Yijing	—	—	30.0	10
11	Tiaoda Taiyang	21.0	6	25	12
12	Wuxi Shangpin	—	—	17	13
13	Shenzhen Tuori	8.0 (a-6)	8	10.0 (a-8)	14
14	Shanghai Chaori	—	—	10.0	15
15	Shanghai Taiyangneg	2.0		8.0	16
16	Zhejing Xiangrikui	—	—	8	16
17	Yunnan Tianda	7.0	8	7.0	17
18	Youlika	3.0		7.0	17
19	Beijing Zhongqing	0.5		7.0	17
20	Shenzhen Jiawei	—	—	5.0	18
Rest		24 (a-6)	—	33.3 (a-20.3)	—
Total		438 （a-12）	—	1088.0 （a-28.3）	—

Fig 4-8 shows the solar cell production of China in 2000-2008. Clearly, since 2002, Cell industry has entered a rapid development period with incredible speed. Fig 4-8 shows both c-Si cell and a-Si thin-film cell production and the boosting trend.

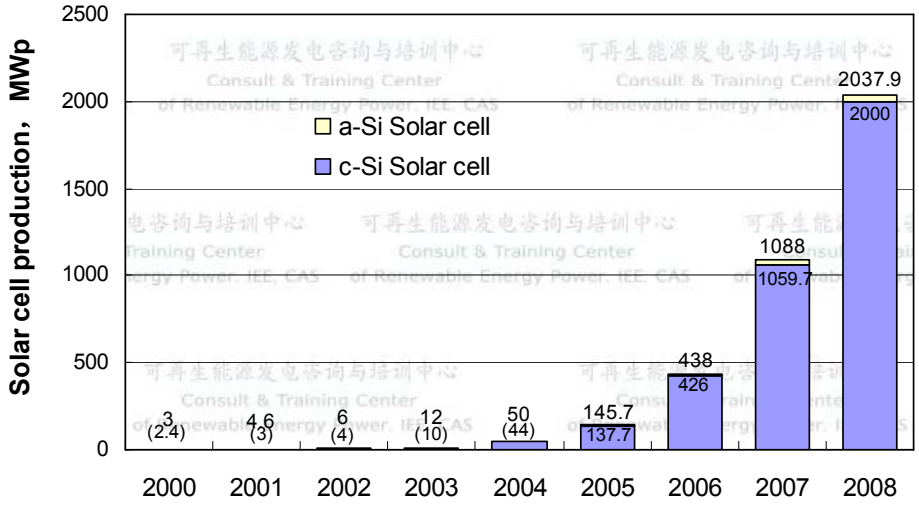


Fig 4-8 Solar cell production output of China in 2000-2008

The Chinese large scale solar cell fabrication has been performed by introducing

the advanced manufacturing line. The newest equipment and related technology of cell producing could be bought in the international market. Solar cell production technology of Chinese leading enterprises basically kept pace with the international advanced level. The average energy consumption of solar cell is 220kWh/kWp, near to the international best level.

2）A-Si thin film cell

In recent years, as the virtues of low cost and better performance of low-light, a-Si solar cell has been paid great attention, the manufacturing industry developed rapidly. The single-junction a-Silicon cell was the mainstream in China before 2004. After 2.5MWp bi-junction a-Si cell production line was introduced by Tianjin Jingneng in 2004; bi-junction a-Si cell developed quickly. At the end of 2008, nearly 20 enterprises engaged in the production of a-Si thin film solar cell in China, with the total production capacity of 134.9MWp/yr. The a-Si cell production is 28.3 MWp in 2007, 37.9 MWp in 2008. 11 major manufacturers and the production in 2006, 2007, 2008 is shown in Tab 4-9. Fig 4-9 shows the a-Si cell production output of China in 2000-2008.

Tab4-7 Production of a-silicon cell in 2006-2008 Unit：MWp

No.	Company	2006	2007	2008
		Pro.	Pro.	Pro.
1	Shenzhen Tuori	6	8	11
2	Shenzhen Chuangyi	2	4	6
3	Beijing Shihua	—	1	5
4	Tianjin Jinneng	1.2	2.0	4
5	Fujian Jintaiyang	—	2	2.5
6	Shenzhen Riyuanhuan	1	1	2
7	Zhejiang Fusheng	—	1	2
8	Shenzhen Hengyang	—	1	1
9	Harbin Gerui	—	1	1
10	Heilongjiang Hake	1	1	1
	Rest	0．8	6.3	0.9
Total		12	28.3	37.9

Fig 4-9 a-Si solar cell production output in 2000-2008

It can be seen from Fig 4-9, since 2004, a-Silicon thin-film cell industry in China entered a period of rapid growing. Analysis of the development drive is as: first, the drive force of the world PV market; second, the maturation of thin-film cell technology; third, the shortage of poly-crystalline silicon materials has greatly restricted the poly-crystalline Si PV industry before the outbreak of the global financial crisis, so as to accelerate the development of thin-film cell industry.

A large number of companies plan to build the higher technological level a-Si/μc-Si laminated cell production lines by introducing, Suntech Power (Shanghai) and Hebei Xinao introduced 50MWp bi-junction a-Si/μc-Si cell production line respectively. A number of companies established their own R & D center, self-manufactured equipment to expand production capacity. Once these cell production lines are completed and put into operation, Chinese thin-film cell industry will be improved to a new height.

The a-Si thin-film cell is still facing some problems, such as low efficiency and the attenuation, shorter life span than c-Si, and low recognition by market. In addition, the thin-film cell technology is in the stage of technology improving and updating, equipment is not stereotyped, the initial investment is high.

4. module encapsulation

C-Si PV module manufacturing is to connect solar cell, encapsulate, to protect the electrode contact, keep from erosion of interconnection, and avoid the fragmentation of the cell. The quality of encapsulation will directly affect the life span of PV module.

The Chinese PV module encapsulating is a stage in which the techniques is the most matured in the PV industry chain, localizing degree of producing equipment is highest, lowest threshold of industry entry, and largest number of enterprises, fastest

expansion, and the largest production. In the PV industry chain, PV module encapsulation stage needs small investment and short construction cycle. For the lower threshold of fund and technology, the advantages of low labor cost can be made best of use, PV module encapsulating industry is the most rapidly developed. According to the statistics, more than 330 enterprises engaged in PV module encapsulation, the encapsulating capacity was 3.8 GWp, the production capacity of PV module was about 5GMp/yr in 2008.

Since China large-scale PV market was not started-up, most of PV modules were exported to abroad, mainly Europe and the United States. The production output of PV module of China in 2008 reached 3,000 MWp, accounting for 44% of the global production 6,850 MWp.

Just like the cell fabrication, as the latest equipment and related technology could be purchased in the international, PV module encapsulation technology keeps the pace with the international level; energy consumption reach 44 kWh/kWp.

5. The associated equipment manufacturing in PV industry

1) Manufacturing equipment of poly-crystalline silicon

The $SiHCl_3$ synthesis equipment and fractionating tower could be made in China. For example, the synthesis equipment of $SiHCl_3$ and rectifying tower in Luoyang Zhonggui and Ermei semiconductor Co., Ltd are designed and manufactured by domestic suppliers; after reducing furnace of 12 double-bars was made and put in operation in Ermei semiconductor and Luoyang Zhonggui, Luoyang developed another product 24 double-bars $SiHCl_3$ reducing furnace of normal pressure, and the 24 double-bars reducing furnace of high pressure are being researched. In 2008-2010, there will be a large number of poly-crystalline silicon-producing lines being put into work. With the fast development of poly-crystalline silicon industry, all kinds of poly-crystalline silicon production equipments, including tail gas recovery equipment, will be gradually localized.

2) The manufacturing equipment of ingot/wafer

The mono-crystalline silicon ingot growth furnace: as the key technology, mono-crystalline silicon ingot growth furnace is mature in China, which had near 40 years' history. In recent years, with the drive of PV market, the production output of mono-crystalline silicon ingot growth furnace has risen steeply; the sales increased from RMB 800 million in 2004 to RMB 0.8 billion in 2007. The quality of domestic mono-crystalline silicon furnace could meet the demand of photovoltaic industry; the price is just 1/3-1/2 of that of foreign products, so that majority product is adopted. At present, there are more than 2400 mono-crystalline silicon ingot growth equipments in China, the majority of which are made in and by China. More than ten enterprises

involved in manufacturing of the mono-crystalline silicon growth furnace in China, including Beijing Jingyuntong, Jingke (Xi'an University of Tech), Shang Hanhong, Beijing Jingyi, Ningjin Solar(Jinglong Group), Changzhou Huasheng Tianlong, Huade (Xi'an University of Tech), Xian Lijing, Kaikesi, and China Electronics Technology Group No. 48 Institute etc. The sales quantity of the Chinese mono-crystalline Si furnace was 400 and 800 in 2006 and 2007 respectively, which can meet the domestic market demand, and batch of which was exported as well.

The poly-crystalline silicon ingot furnace: with the drive of the demand of market, the localization of poly-crystalline silicon ingot furnace is sped up, which is changing the situation of poly-crystalline silicon furnace relying on importing. At present, many enterprises developed polycrystalline silicon ingot casting furnace, such as China Electronics Technology Group No 48 Institute, Beijing Jingyuntong, etc. Now the series qualified product of 240-270kg and 400-460kg have been developed, and the batch of producing and sales has begun. It's predicted that the products will be used widely in China next few years.

Silicon-slicing equipment: The present silicon-sawing equipments are mainly depends on importing. As a result of demand, many companies are developing solar-grade silicon sawing equipment now. The silicon wire sawing equipment made by Shanghai Rijin are being tested now, another one developed by a company in Gansu has passed the product identification; Hebei Ningjin Solar Co., Ltd are in research. The Si sawing equipment localization can be realized soon.

3) Solar cell manufacturing equipment

Solar cell manufacturing equipment includes cleaning machine, diffusion furnace, plasma etching machine, sintering furnace, PECVD-SiN furnace, and screen printer, sorting machine, etc.

Diffusion furnace, plasma etching machine, dryer, etc have been localized already, the manufacturers include former Electronic Ministry No. 48 Institute, Beijing 7-Star Huachuang Co, etc, and has been used by most of main cell producers.

Wafer cleaning machine has been made domestically as well; the main manufacturers are Shenzhen Jiejiachuang Co., Beijing 7-Star Co., etc. About half of solar cell production lines use the domestic cleaning machine.

The semi-automatic screen printing machine developed by former Electronic Ministry No. 45 Institute has been used in large number, and fully automatic screen printing machine and automatic sorting machine are being developed, which can be put into the market in one to two years.

The sorting machine developed by Solar Energy Institute of Xi'an Jiaotong University, Solar Energy Institute of Xi'an Jiaotong University, and the Qinghuandao

Bosuo Co., Ltd, etc can be used in the small scale producing line with lower automation. The No. 48 Institute and other institutions are developing the complete automatic sorting machine, it is predicted that the products can be in market in one-two years.

4) PV module encapsulating equipment

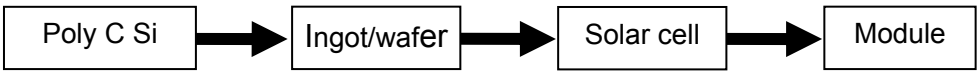
PV module encapsulating equipment has attained the localization. More than ten companies, such as Qinhuangdao Aoruite, Shanghai Shenke, Qinhuangdao Boshuo, etc. can supply the laminating machine. The above three suppliers have more than 90% of the whole market share. 90% of the laminating machines of China's first 30 PV module encapsulating enterprises are from the above three companies. Qinhuangdao Aoruite could provide a variety of laminating equipment, Shanghai Shen Ke usually provides large-scale automatic encapsulating equipment.

The manufacturers of laser scribing apparatus include Wuhan Sangong, Shenzhen Dazu, Zhuhai Yuemao, etc. The manufacturers of PV module testing facilities include Solar Energy Institute of Shanghai Jiaotong University, and Solar Energy Institute of Xi'an Jiaotong University, etc. All the PV module production lines can adopt the domestic equipment; cost is in superiority, but not with fully-automation producing. The high automation in-series welding machine of and the cell-laying machine are being developed and commissioned.

4.3 Analysis on the cost, price of domestic and international PV market

More than 98 % of Chinese PV module product is exported oversea and the price of PV modules in China is basically close to the international price. In 2008, the average global price of crystalline silicon PV modules has increased by some that in 2007, averagely from USD 3.6 to USD 4.26/ Wp. With the outbreak of financial crisis, the price of PV modules has dropped sharply to $2.8/Wp or below. The price of PV module maybe decline further, as the financial crisis become more serious.

Analysis on the market data of Mar 2009, the cost and price of PV manufacturing components in China and overseas are shown in Tab 4-10, in which poly-crystalline Si price estimation is based on the spot price of poly-crystalline silicon US$90/kg and silicon consumption of cell 7g/Wp, so the poly-crystalline silicon material consumption is 144 Wp cell / kg Si, equivalently the spot price US$0.63/Wp.



Price (Domestic)	0.63		1.19		2.02		2.63
Cost (Domestic)	0.35	0.3	0.93	0.3	1.49	0.3	2.32
Value-added (Domestic)	0.28		0.26		0.53		0.31
Price (Overseas)	0.56		1.21		2.16		2.96
Cost (Overseas)	0.30	0.30	0.86	0.50	1.71	0.55	2.71
Value-added (Overseas)	0.26		0.35		0.45		0.25

Fig 4-10 Cost and price of PV manufacturing components in China and overseas ($/Wp)
Partial data source: Barclays Capital in the United States, Industry Report，February 09, 2008

The domestic and international composition proportion of the cost of PV modules is different. As is shown in Tab 4-10 and Fig 4-11, the total cost of the domestic PV modules is US$1.53/Wp, in which the cost of poly-crystalline silicon is US$0.63, and accounts for 29.3% of the total cost. In contrast, the total cost of international PV modules is US$1.91/Wp, in which poly-crystalline silicon is $0.63, accounting for 29.3% the total cost. In contrast, the ration of poly-crystalline silicon to the total cost of PV module made by the domestic companies is higher than that by the foreign companies. For the reasons, in recent years, PV industry developed dramatically, which results in the rapid increasing of the polycrystalline silicon demand; however the production of the poly-crystalline silicon is little, which led to the severe shortage of poly-crystalline silicon and the continually increasing of the price of poly-crystalline silicon. Data shows that, in 2005 the domestic price of poly-crystalline silicon was US$66/ kg; in the fourth quarter of 2006 it was over US$300/ kg, and in 2007 a new record was US$400/ kg.

Tab 4-10 Composition of cost of PV modules Unit：US $

Stage	Poly-crystalline silicon	Ingot/wafer	Solar cell	PV module
Cost(Domestic)	0.63	0.3	0.3	0.3
％ of Total	41.2	19.6	19.6	19.6
Cost(Overseas)	0.56	0.30	0.50	0.55
％ of Total	29.3	15.7	26.2	28.8

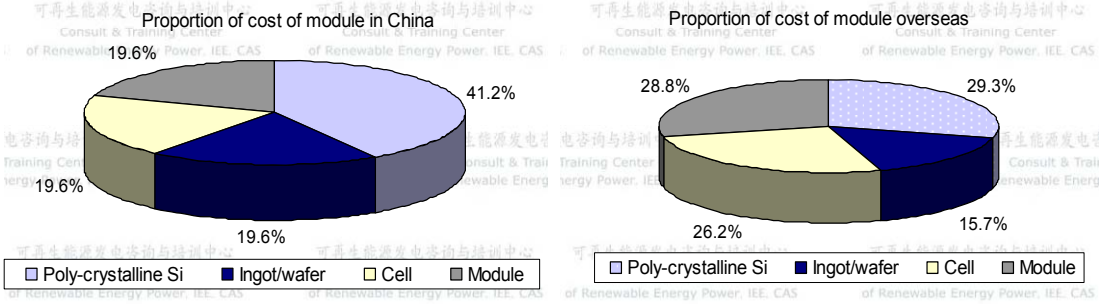


Fig 4-11 Chinese and international PV module cost composition

The sum of the manufacturing cost of three stages of ingot/wafer, cell, and module production is only US$0.9/Wp in China, accounting for 58.8% of the total cost. While the average international total cost is US$1.35 /Wp [5], which is 70.7% of the total cost. Comparing with the foreign, the characteristics of Chinese PV products is lower in labor cost, lower in the price of land, lower in industrial electricity fee, with some leading technology (thin thickness of wafer), which, to some degree, counteracts the disadvantageous elements of Chinese PV industry, i.e. high cost of poly-crystalline silicon.

In fact, before the outbreak of financial crisis, comparing with the foreign PV industry, the value-added space of domestic PV manufacturing is smaller. In the first half of 2008, as the price of poly-crystalline silicon was US$260/kg, the value-added space of poly-crystalline silicon production is big, with the added value of USD1.62/kg, it is 2.3 times of the foreign. The added value of the ingot/wafer, solar cell, and PV module producing value is US$0.26/Wp, US$0.68/Wp, and US$0.43/Wp respectively, all of which are lower than that of the same stage. With the outbreak of financial crisis, the decline of poly-crystalline silicon price made the added value of each manufacturing stage in China same with the foreign, as shown in Fig 4-12.

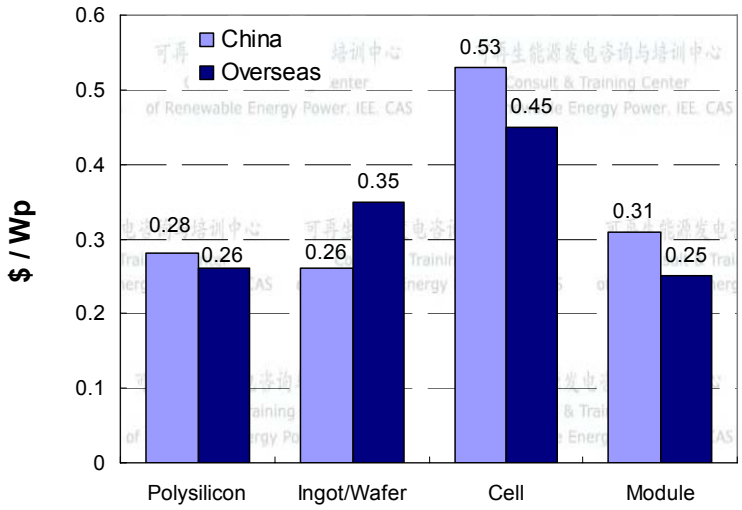


Fig 4-12 Comparison on the value-added of each manufacturing stage

As seen from Fig 4-11, Poly-crystalline silicon material is the major factor of PV

module cost in China. The truth is that, in recent years, Chinese PV industry develops very quickly, the demand of poly-crystalline increased fast; however the domestic production of polycrystalline Si is small, which results in the extreme shortage of poly-crystalline Si and the rising of the price. It was reported that with the breakout of the financial crisis, the price of poly-crystalline silicon materials declined sharply, dropped to US$80-90/kg. In the condition that the total manufacturing cost of the wafer, cell, and the module is USD0.9/Wp. If poly-crystalline silicon price declines to USD 60/ kg, the cost of PV module could be reduced to USD 1.32/ Wp; if poly-crystalline silicon price falls to USD 50/ kg, the cost of PV module could be reduced to USD 1.25/ Wp. As shown in Fig 4-13 that poly-crystalline silicon price has impact on the cost of domestic PV modules.

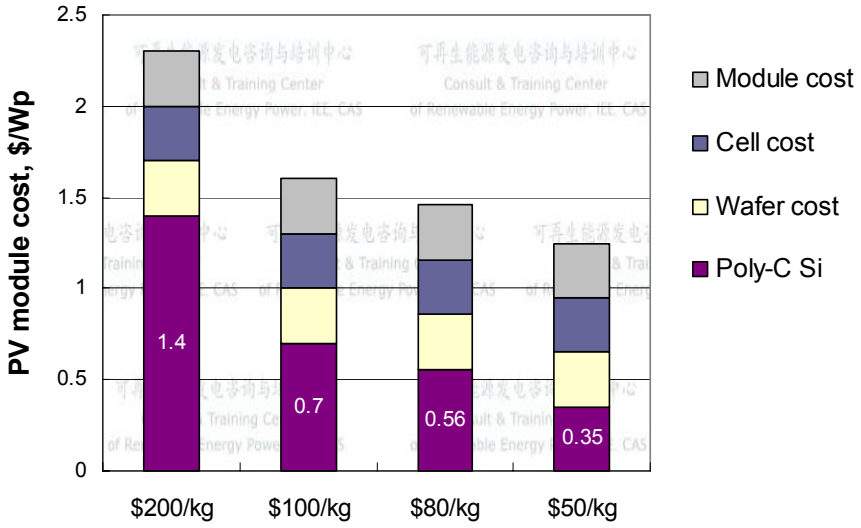


Fig 4-13 the impact of poly-crystalline silicon price on the cost of PV module

The general trend is that the poly-crystalline silicon price will go even lower. On the one hand, with the effect of the financial crisis, the global shortage of poly-crystalline silicon has been mitigated, the price is becoming rational; on the other hand, the global new poly-crystalline silicon project production began to reach the designed capacity; in particular, more than 10 large-scale poly-crystalline silicon projects in China have been put into operation, which alleviated the shortage of poly-crystalline silicon. The domestic poly-crystalline silicon projects planned in 2006 have come to the stage of ending, the present planned poly-crystalline silicon projects in China is of 10,000 tons production capacity, 40,000 tons in-construction production capacity. It is estimated that poly-crystalline silicon production will reach 10,000 tons and 30,000 tons in 2009-2010, with the projects being put into operation one by one.

4.4 Chinese C-Si PV technology developing potential and trend of cost changing

Chinese manufacturing technology of c-Si PV modules have made tremendous progress in the recent years. For example, a variety of R&D work have made evident achievement by aiming at the deceasing of the cost, for example, the purification technology of poly-crystalline Si has made a breakthrough, the thickness of wafer continues to be thinned, and the efficiency of cell was improved continuously and so on.

1. Purification technology of poly-crystalline silicon gained breakthrough

Domestic company introduced, digested, and absorbed the poly-crystalline silicon purification technology of “Modified Siemens Arts and Crafts”, had made independent innovations in the practice in the past two years. Many independent intellectual properties were achieved. The poly-crystalline silicon was no longer controlled by the foreign companies, for the breakthrough of poly-crystalline Si purification technology. The domestic energy consumption level is getting closer to that of the international best level with zero pollution emission in the whole process of poly-crystalline silicon purification. It is estimated that the production cost of poly-crystalline silicon could be reduced to US$30/ kg next 2-3 years or more lower. The decreasing of the poly-crystalline Si material will directly bring about the manufacturing cost of PV module. If the price of poly-crystalline silicon materials can be reduced to US$40/ kg, the cost of PV modules will be dropped to US$1.18 / Wp.

2. Thinning of wafer thickness

Reducing wafer thickness is an effective method to lower the silicon material consumption and cost. The wafer thickness of commercial solar cells has been reduced from 400-500μm in 1970s to the current thickness of 180-200μm over the past 30 or so years, decreased by half, which plays important role in cost decreasing of solar cell. At present, the domestic producers’ solar cell thickness has been up to 180μm of international level, as shown in Tab 4-11 and Fig 4-14. In the condition that the fragmental rate of wafer does not increase further, if the thickness of solar cells is reduced from 180μm to 160μm, the silicon consumption can be reduced by 10%; the cost of PV module can be decreased by 6%.

Tab 4-11 Decline of thickness of C-Si cell

Year	Thickness，μm	Silicon consumption，Ton／MWp
70s	450～500	>20
80s	400～450	16～20
90s	350～400	13～16
2006	200-220	10-11
2007	180-200	9-10
2008	180	~7
2010	160-180	~6

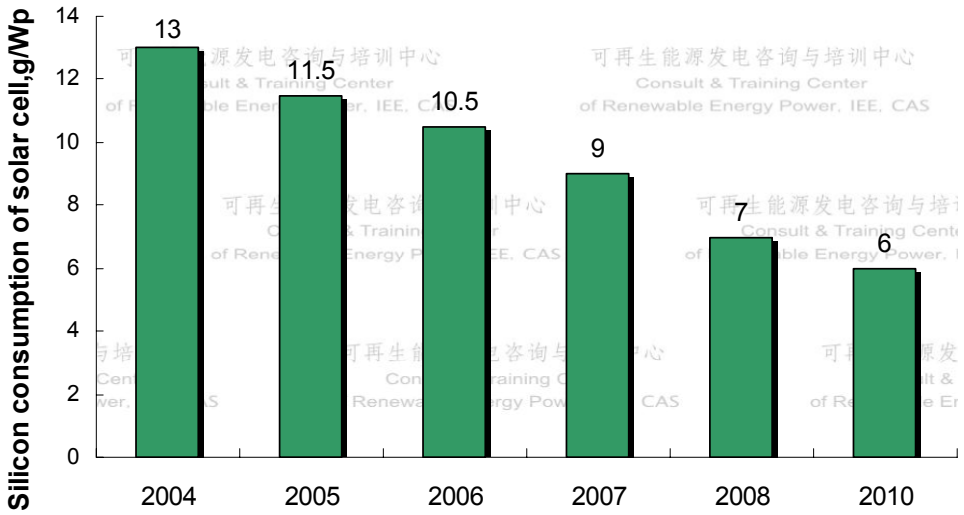


Fig 4-14 Reduction trend of crystalline Si consumption in 2004-2010

3. Continuous increasing of the cell efficiency

The efficiency of mono-crystalline silicon cell in the laboratory has been improved from 6% in 50's to 24.7% at present; the efficiency of poly-crystalline silicon cell has reached 20.3%. As a result of the transferring new technologies into the industrial production, commercial solar cell conversion efficiencies have been improved always. The efficiency of commercial silicon cells is up to 14% -20% (Mono-C Si cell 16-20%, Poly-C Si 14-16). Once the silicon cell efficiency is improved by one percent, solar cell costs will be reduced by 10%.

4. Enlarging the producing scale

According to *Chinese PV industry report 2007*, the relationship between manufacturing scale and production cost can be illustrated by the LCR (Learning Curve Rate), i.e. the percentage of the production cost decline, as the production scale expand by half. With regard to the solar cell manufacturing, LR = 20% (including the technical improvement), that means the manufacturing scale is doubled, and the production cost was decreased by 20%.

Increased the scale of manufacture is the major factor of the cost reduction in solar cell production. From the beginning of Chinese solar cell industry in 1980s, the production capacity of solar cell increased from 4.5MWp in 2000 to 2.9GWp in 2007. Solar cell manufacture per factory increased from 0.1-0.2 MWp/yr in 1980s to 0.1-2MWp/yr in 2000, 10-350MWp/yr in 2006, 10-500MWp/yr in 2007. By the end of 2008, Suntech Co. Ltd has formed annual production capacity of 1GWp.

5. Localization of auxiliary material

The auxiliary material for PV module in China also developed rapidly. For example, aluminum slurry, EVA, PV module, ultra clear glass, and connectors can be

made in domestic company, and formed the large-scale production, which can meet the demand of Chinese PV industry, and make the cost of PV decreased by some. With summarizing the above, the cost of PV modules is expected to drop to RMB 9.6 / Wp (US $1.4/Wp) or even lower by 2010.

4.5 Study on the cost of PV power system and the feed-in tariff

1. Estimation on the cost of on-grid PV power system and the feed-in tariff

1) System structure

Grid-connected PV power system is the PV power system connected to the utilities grid and supplying electricity to the grid. It is the main direction as PV power enters the large-scale commercialized stage and it is an important component of electrical power system.

Solar energy was converted into the electricity of direct current by PV array; inverter converted DC into AC and connected to grid. Grid-connected PV power system is made up of PV array, grid-connecting inverters and etc.

2) Tariff estimation of the on-grid PV power system

Initial conditions:

(1) Initial investment

In 2008, the cost of grid-connected PV power system is about RMB 40,000/kWp. PV module price decreased sharply after the outbreak of financial crisis. According to Dunhuang 10MW PV project bidding, the domestic PV module has dropped to RMB 14-16/Wp. The cost of PV power system fell to RMB27500 /kWp, the components of initial investment is shown in Tab 4-12.

Tab 4-12 Initial investment of 1kWp grid-connected PV power system

Item	Investment（RMB 10,000）	% of Total
PV modules	1.50	54.5
Inverter	0.25	9.1
Fittings	0.5	18.2
Miscellaneous	0.5	18.2
Total	2.75	100

(2) Annual operation and maintenance cost

Operation and maintenance cost = fixed asset investment × operation and maintenance rate.

PV power system doesn't consume fuel. BIPV and open-field PV system could run automatically without watch, the cost of the consumables and maintenance is little. Operation and maintenance fee rate are about 0.2%.

(3) Salary and welfare

BIPV system does not need watch personnel, with only part-time management needed; the rate can be as 0.8% of the initial investment. Even though in the open field PV power plant, the management is needed, the work is little; the fee rate is 0.8%.

(4) Replacement of components and overhauling

PV modules' life span is usually 20-30 years, and no battery bank is needed for grid-connected PV power system, therefore PV module and battery replacement is unnecessary. The inverter and other electrical devices in life need to be replaced partially. Based on the primary investment of the inverters, the ratio of the replacement and overhauling cost of the total electrical appliances in life span is set as 8-10% of the initial investment.

(5) Depreciation

Depreciation fee = original value of fixed asset × depreciation ratio

Among them, original value of fixed asset = initial investment × 80%;

Depreciation ratio = 1/depreciation period (years) × 100% = 1/20 × 100% = 5%.

(6) Financial fee

It is assumed that 80% of initial investment is from loan, 20% of it is from equity capital.

Loan period: 20 years.

Interest Rate: 6.12%.

Internal rate of return (IRR): 10%.

(7) Taxation rate

PV project is free of income tax, value-added tax rate is 8.5%, urban construction tax is 5% of value-added tax, and education added tax is 3% of value-added tax.

(8) Power generation estimation

Electricity output of PV power system mainly depends on the local solar energy resource, the system's operation mode, and efficiency in every phase of system. The electricity output is different from that of PV systems.

(9) System efficiency

The installation angle of BIPV is restricted by the building's structure; the system efficiency is approximately 74% (inverter efficiency is 95%, orientation loss 15%, and other efficiency of 92%), orientation loss is bigger.

Basically no loss of solar orientation, open-field PV system needs boosting transformer in the plant field, and dust shading effect on the PV module surface in the desert areas is more serious than that in urban areas. The system efficiency is 80%.

(10) Annual effective hours

The annual effective hours of different PV systems hours is shown in Tab 4-16. In the calculation, the annual effective hours is taken as 1500, which means that the electricity output of 1kWp PV system is 1500kWh/yr.

Tab 4-13 annual effective hours of different type of PV power in China

Type	Off-grid PV power station	On-grid BIPV	Open field on-grid PV power
Annual Max	1,668.3	1,815.5	1,962.7
Annual Min	896.5	975.6	1,054.7
Annual average	1,095.7	1,192.4	1,289.1

Note: annual effective hours= annual usable hours × integrated efficiency of the PV power system

Data source: *Chinese PV Industry Development Report in 2007*

Summarizing the above, the calculation formula of tariff is as follows:

Feed in tariff (RMB/kWh) = (Annual equity capital income + annual repayment to the loan of capital sum + annual interest of loan + depreciation fee + annual operation cost) / yearly electricity output

When the annual effective hours are 1,500, the tariff of PV power is estimated as RMB 2.0 /kWh; if annual effective hours is1, 800 hrs, the tariff could be reduced to RMB 1.68/kWh.

3) sensitivity analysis

(1) Analysis on sensitivity on the initial investment

The initial investment is the key part of PV power cost, with 60% of the cost. Along with technological progress, improvement of PV efficiency, service life extension, and economics of scale, the initial investment will decline with the reduction rate of 10%/yr, by referring the prediction of the international [10]. As is shown in the Fig 4-13, PV power tariff declines with the reduction rate 5%/yr and 10%/yr of initial investment.

Based on the initial investment of RMB 27,500/kWp, annual effective hours of 1500, the reduction rate of 10% of initial investment, the tariff of PV power could be reduced to RMB 1.0/kWh in 2016. If the solar cell technology makes a huge progress, the cost of material drops dramatically, the goal of the tariff dropping to RMB 1.0/kWh could have achieved ahead of time.

Fig 4-15 Trend line of PV power tariff

(2) Sensitivity analysis on annual effective hours

In different regions, the power generation of the same PV power capacity is different, due to the different radiation resource and the effective hours. As shown in Fig 4-14, with the reduction rate of 5%/yr and 10%/yr of the initial investment, and with the annual effective hours of 1000, 1400, 1800, the PV power tariff declines respectively.

Based on the initial investment of RMB 27,500/kWp, the reduction rate of 10%/yr, annual effective hours of 1800, the tariff is RMB 1.68 Yuan/kWh in 2009, and will be RMB 0.89 Yuan/kWh in 2015.

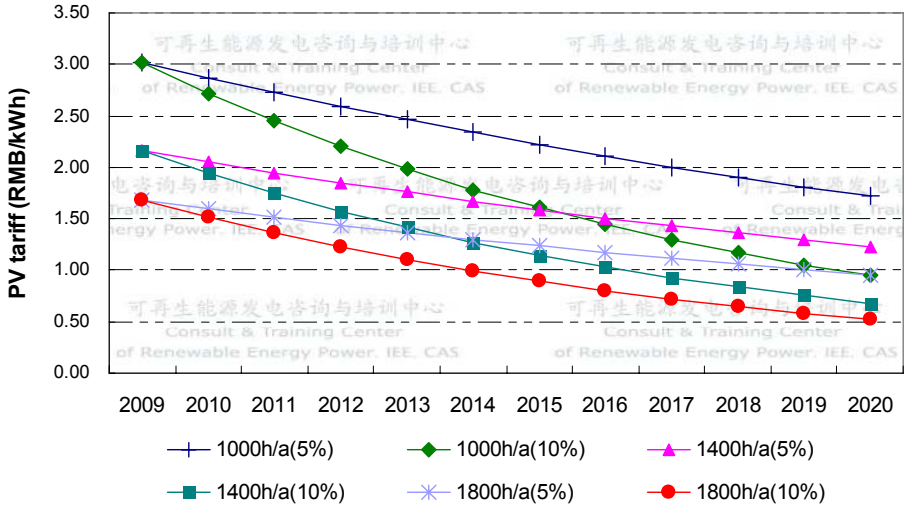


Fig 4-16 Trend line of PV power tariff (annual effective hours: 1000, 1400, 1800 h/a)

(3) Cost comparison between PV power and coal-fired power

According to this research on the conventional coal-fired power cost, the cost of coal-fired electricity was RMB 0.56 Yuan/kWh in 2007, including the internal power generation cost of RMB 0.22 Yuan/kWh, and the external cost of RMB 0.34

Yuan/kWh resulted from coal mining, transporting, and the coal combustion, and so on. According to the statistics, the average coal price increased from RMB 121 / ton in 2002 to RMB 507 / ton in 2007, with an average annual growth rate of 33%. As a conservative estimate, the coal-fired power cost with annual growth rate of 5%/yr may increase to RMB 1.01 Yuan/kWh in 2020. In addition, the cost of coal fired power may increase by additional 0.5% based on the 5%, for that the quantity of coal mining has been increased year by year, the shortage of coal resource reserve is being more and more serious, and coal coat and price are continually rising in China, which results in the rapid rising coal-fired power cost, As shown in Fig 4-17, based on the condition that the PV power initial investment is RMB27,500/kWp, with annual effective hours of 1800, the feed-in tariff of PV power is about RMB 1.68/kWh. If the initial investment of RMB 27,500/kWp with annual reduction of 10%/yr, still with the annual effective hours of 1800, and the cost of coal fired power is RMB 0.59/kWh with an annual growth rate of 5%/yr, the PV power cost will be equalized to that of coal fired power feed-in in 2016, with RMB 0.80/kWh or so.

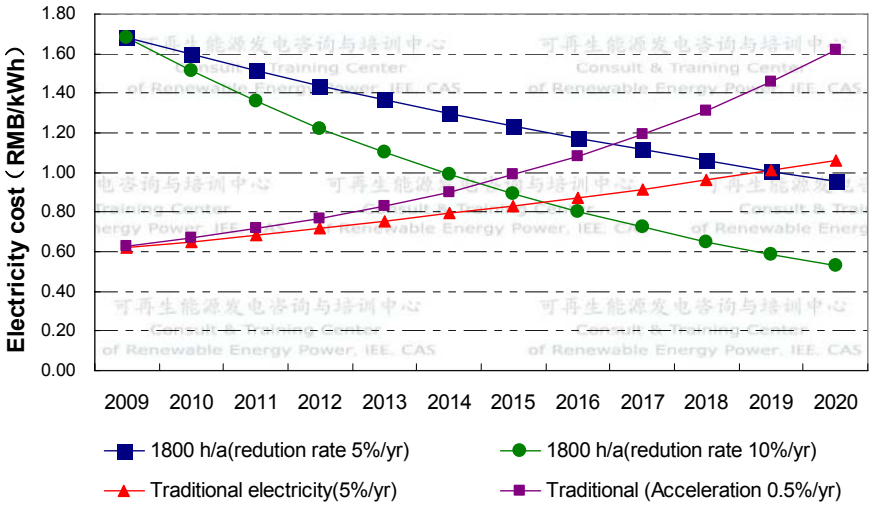


Fig 4-17 PV power and coal fired power cost comparison

2. Foreign PV power tariff forecast and analysis

1) Japan

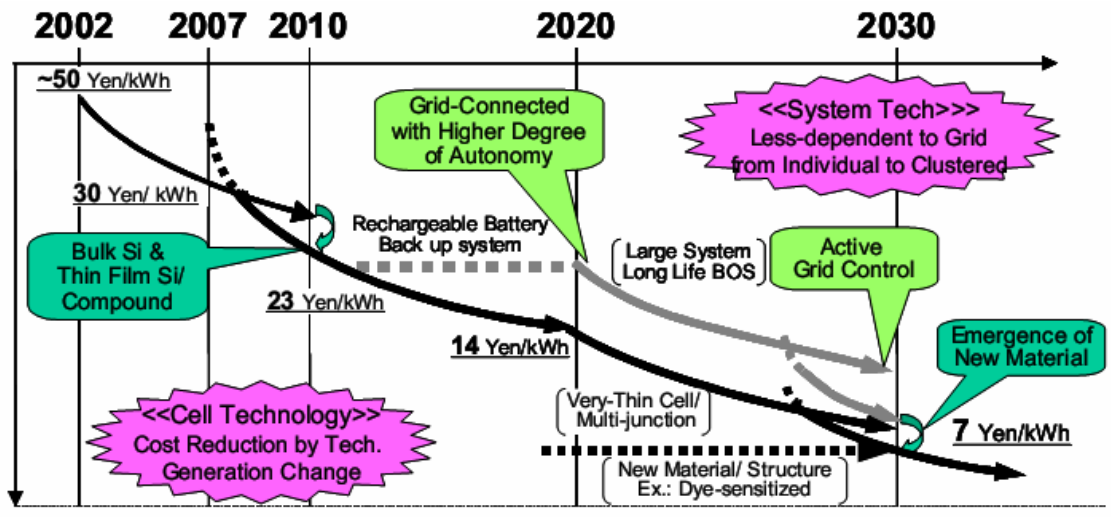


Fig 4-18 Trend of Japanese PV power tariff

Japanese New Energy and Industrial Technology Development Organization (NEDO) made a forecast on PV power, as shown in Fig 4-18 in the research report "*PV Roadmap* Toward *2030*". In Japan, by 2010, the PV power tariff will drop to 23 Yen /kWh (converted to RMB 1.53 Yuan/kWh), 14 Yen/kWh (RMB 0.93 Yuan / kWh) in 2020, 7 Yen / kWh (RMB 0.47 Yuan / kWh) in 2030.

2) Deutsche Bank

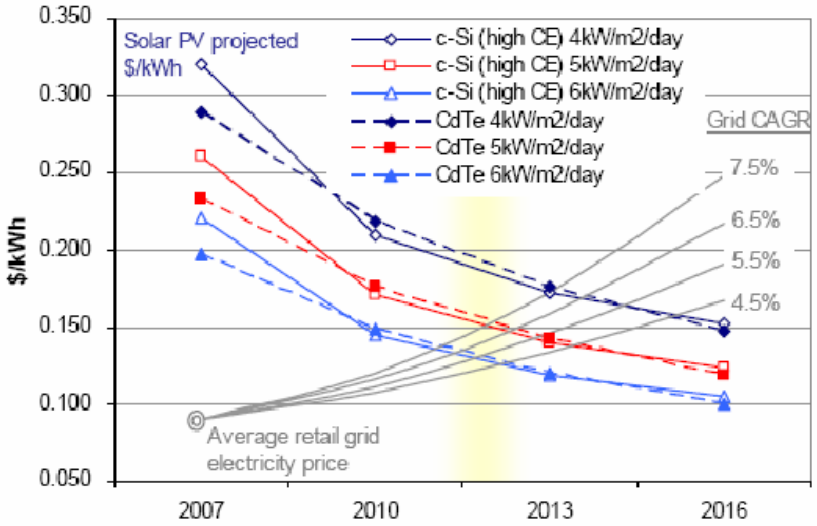


Fig 4-19 Forecast on the cost of PV power by Deutssche Bank

Deutssche Bank made the forecast, as shown in Fig 4-19 in its report "*Solar PV Industry* Outlook *and Economics*" in three different conditions of sunlight (4, 5, 6 kWh/m2/day) regardless of c-Si cell or CdTe, the cost of PV power will drop to USD 0.15/kWh (equivalent to RMB 1.02 Yuan / kWh)by 2016.

3) EPIA and Green Peace

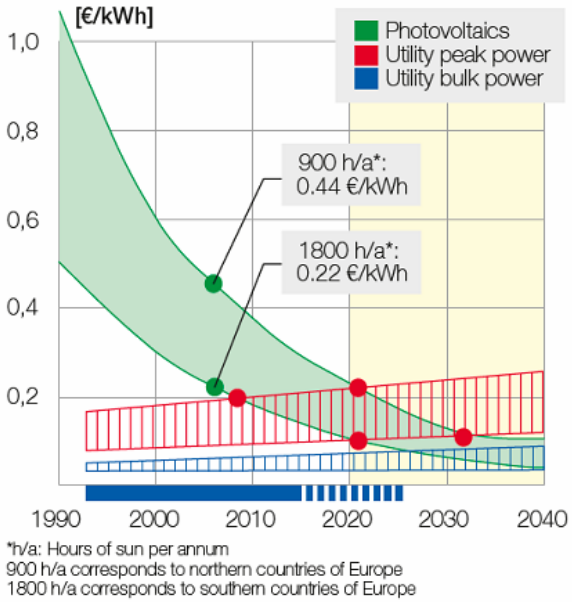


Fig 4-20 Trend line of PV power tariff

European Photovoltaic Industry Association (EPIA) and Greenpeace (Greenpeace) forecast, as shown in Fig 4-20, PV power tariff will drop to Euro 0.16 / kWh (equivalent to RMB 1.5 Yuan / kWh) in 2015, EURO 0.11 / kWh (RMB 1.0 Yuan / kWh) in 2020.

4) Q. CELLS

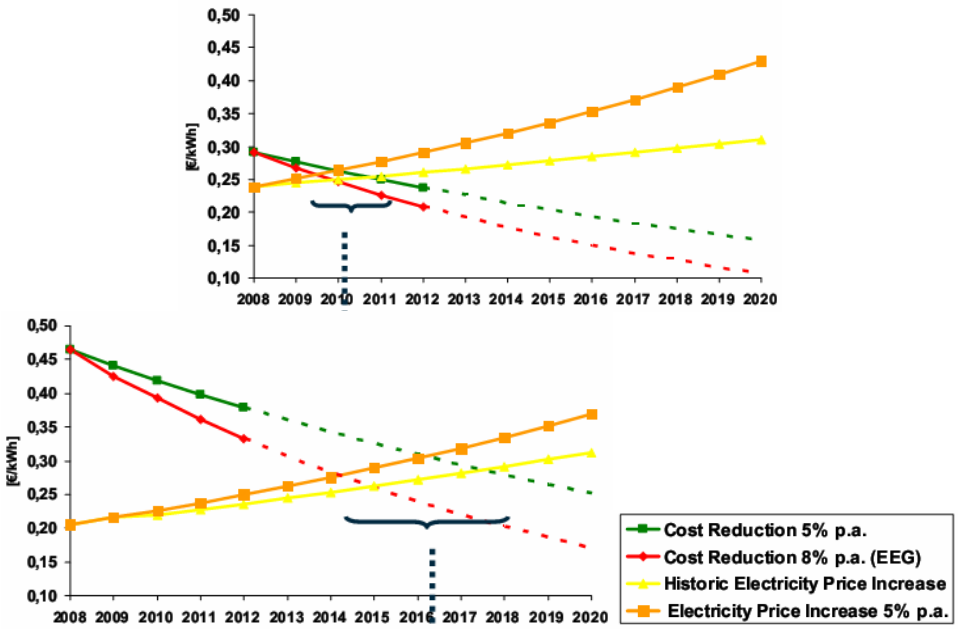


Fig 4-21 Forecast on the cost of PV power by Q.CELLS

As shown in Fig 4-21, the world's top PV producer, Q. CELLS, forecast that, Italy PV power tariff will drop to Euro0.11 / kWh (equivalent to RMB 1.0 Yuan / kWh) in 2019, Germany PV power will be Euro 0.16 / kWh (equivalent to RMB 1.5 Yuan / kWh) in 2020 [8].

By summarizing the prediction of the above research institutions and PV producer on PV power, the PV power cost will drop to USD 0.15 / kWh (equivalent to RMB 1.02 Yuan / kWh) in 2015-2017. The annual growth rate of traditional electricity tariff was increased at 4% rate since 2000, will be 5-7% increasing rate next 10 years. The traditional tariff is estimated to be increased from USD 0.086/ kWh (equivalent to RMB 0.58 Yuan / kWh) in 2006 to 0.16 / kWh (equivalent to 1.06 RMB / kWh) in 2019. PV power may reach the point of USD 0.14 / kWh of conventional power tariff (equivalent to RMB 0.95 Yuan / kWh) in 2016-2017.

3. Off-grid PV power system

1) System structure

The off-grid PV power system is mainly used in the non-electrified region and some special places where are far from the utility grid, such as remote rural areas, herding areas, islands, plateaus, and desert; the off-grid PV power system supplies power for the resident, farmer, and fisherman's basic living electricity such as watching TV, lighting, and broadcast listening; the power units are also used for communication relay station, coastal and inland navigation, oil and gas pipeline catholic protection, meteorology station, and border posts power supply.

2) Analysis on the cost of off-grid PV power

Initial conditions:

- Initial investment: RMB 60,000 / kWp;
- Yearly interest rate: 6.12%;
- Service life span: 20 years;
- Annual effective hours: 800;
- System efficiency: 68%;
- Portion of daily O&M fee to initial investment in life: 10%;
- Portion of technical support to initial investment in life: 25 %;
- Portion of management cost to initial investment in life: 5%;
- Portion of parts replacing cost to initial investment in life: 20%;
- Times of component-replacing: 3.

In accordance with the above, calculation result of the cost of off-grid PV power is shown in Tab 4-14.

Tab 4-14 off-grid PV system O/M cost (averaged to 1kWp) and cost per kWh

Item	Amount（RMB）
Initial investment	60000
Annual daily O&M fee	300
Annual technical support fee	750
Annual management fee	150
Replacement fee each time	12000
Cost on per kWh	14.53

The cost of off-grid PV power system is relatively higher. On the one hand, the system contains energy storage devices- battery, nickel-cadmium battery needs to be replaced three times in 20 years service life time, and the lead-acid battery be replaced 6-7 times in 20 years. On the other hand, the cost of system maintenance is higher because the power systems are located in the remote area, and for the poor transportation.

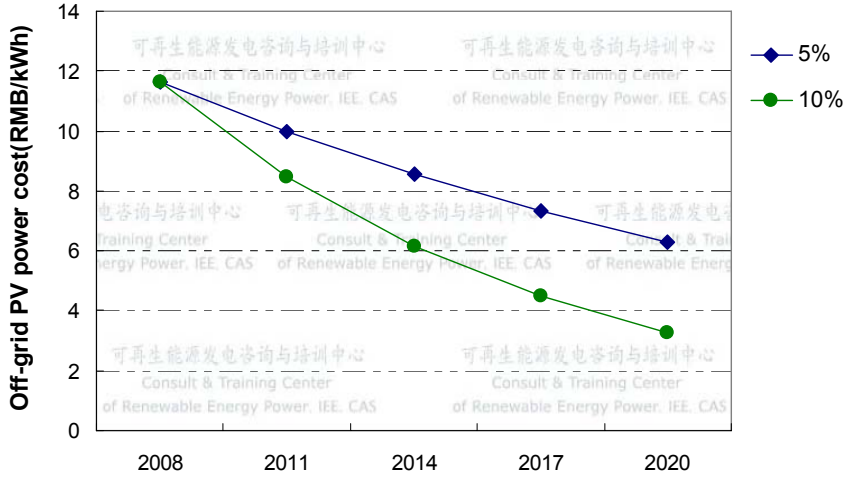


Fig 4-22 Trend analysis of off-grid PV power per kWh cost

Base on initial investment RMB 60,000/kWp of off-grid PV power system, annual effective hours of 800. Fig 4-15 shows the trend of decline of off-grid PV power cost with the reduction rate 5%/yr and 10%/yr from the initial investment. The off-grid PV power cost was RMB 11.6/kWh in 2008, and will drop to RMB 8.5/kWh in 2011, RMB 3.3/kWh in 2020.

4.6 Summary

1. **Characteristics of present PV industry chain in China**：1) Chinese PV industry chain is becoming integrated. The situation of the small crystalline silicon capacity and the large production of c-Si PV module have been changed. The nowadays situation is that, because of crystalline silicon fabrication technology breakthrough, ingot/wafer and solar cell manufacturing developed rapidly, many new PV module enterprises are emerging; 2) PV industry of China developed dramatically. The highest annual growth rate is 300% from 2002 thru

2008; the production output of PV module tops the first in the world in 2007 and 2008. 3) Large investment is on PV industry. The planned capacity of poly-crystalline silicon is over 100,000 tons and its investment more than RMB 100 billion. The formed capacity of ingot/wafer, cell and module capacity is totally 5,000 MWp/yr, with RMB 50 billion on fixed assets investment, the in construction capacity of ingot/wafer, cell and module capacity is 3,000 MWp/yr totally, with RMB 30 billion investment. 4) Some problems exist in Chinese PV industry. PV module highly relies on foreign consumption, the uneven geographical distribution of PV industry. 5) With the outbreak of the global financial crisis, global demand of PV decreases; Chinese PV industry is facing risks, but also having the opportunity for developing.

2. **Status of Chinese PV industry chain**：1) The purification technology of poly-crystalline Si made breakthrough. The lowest energy consumption of manufacturing poly-crystalline Si is 127kWh/kg, which closes to the top level of the world. Over 10 companies begin to produce poly-C Si, and the production output is about 4,500 tons in 2008; 2) the manufacturing technology of ingot/wafer has reached the international advanced level, the energy consumption of advanced enterprises is only 62 kWh/ kg, and the main production equipment can be made in China by Chinese companies. Total ingot/wafer production output is 20,000 tons in 2008; 3) the manufacturing technology of solar cell is advanced. The technology of the first class companies keep pace with the international, the energy consumption is about 220kWh/kWp. The solar cell production is over 2GWp in 2008; 4) the encapsulation technology of PV module is mature; the main production equipments can be made by local companies. Production capacity of PV module is about 5000WMp/yr, and more than 330 enterprises are engaged in PV module encapsulation.

3. **The cost and price status of PV industry chain**：In 2008 the average global price of crystalline silicon PV modules has risen to USD 4.26 /Wp, higher than that in 2007. With the outbreak of financial crisis, the price of PV modules has dropped sharply to USD 2.8/Wp. The price of PV modules in China is basically the same with the international, but the composition proportion of the cost of PV modules is different. The poly-crystalline silicon material cost accounts for 41% of the total cost of PV module in domestic companies, while that is 29% in the cost of the foreign PV module. Domestic PV module product has the feature of higher poly-crystalline Si material cost, lower labor cost, and etc.

4. **Technology potential and cost trend of PV in China**：The cost and the price of c-Si PV modules decline is an inevitable trend. On the one hand, the Chinese manufacturing technology of c-Si solar cell have made tremendous progress.

The main expression is that the purification technology of poly-crystalline Si has made a breakthrough, the thickness of wafer continues to be thinned, and the efficiency of cell was improved continuously and so on. On the other hand, the price of poly-crystalline Si is becoming rational, the spot price of poly-crystalline Si dropped by 70 percent to the high price in 2008. This will greatly reduce the cost of PV module.

5. **The cost and tariff of PV power system：** Along with technological progress, improvement of PV efficiency, life extension, and economics of scale, the cost of PV power will decline gradually. On the basis of initial investment of RMB27, 500/kWp, annual effective hours of 1800, the feed-in tariff of PV power is about RMB 1.68/kWh. If the initial investment of RMB27500/kWp with the annual reduction of 10%/yr, annual effective hours of 1800, the cost of traditional electricity is 0.59/kWh with annual growth rate of 5%/yr, the PV power can be equalized to the tariff of coal fired power in 2016, around RMB 0.80/kWh.

References

[1] Chen Qiyu and She Feifei, *Excellent performance of integrated PV enterprise in 4-Season Newspaper*, http://www.cs.com.cn/ssgs/04/200903/t20090305_1778491.htm

[2] Zhao Yuwen, Wang Sicheng, Wang Wenjing , Li Xudong,etc, *Research report on China PV industry Development (2006-2007)*

[3] Jiangsu Zhongneng Co., Ltd., *A special report on the progrss of poly-crystalline silicon project to NDRC*.

[4] *PV industry projects in Hebi*, http://www.hbzs.gov.cn/zsxmInfo.asp?Id=485

[5] Ryan Wiser, *Cost and Price of PV Manufacturing Components*

[6] Li Junfeng, Wang Sicheng, etc., *China PV Development Report 2007*, China Environmental Science Press

[7] Li Junfeng, *The latest analysis on PV market*

[8] *Q-CELLS SE REPORT AS OF 30 SEPTEMBER 2008*.

5. Major Factors Impeding Chinese PV Market Development

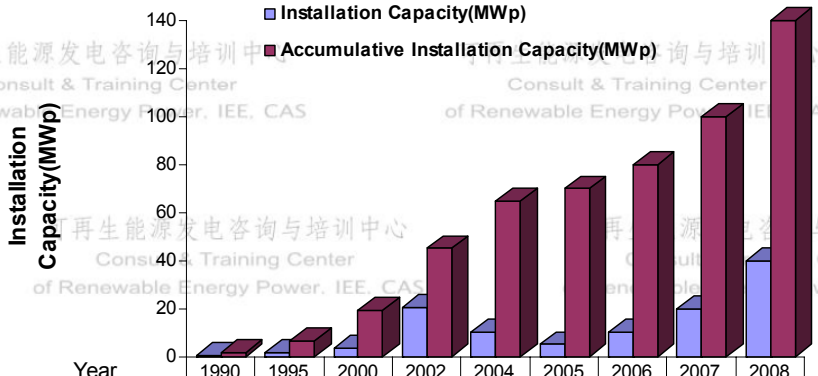
5.1 Chinese PV market development and the characteristics

1. PV market development status in China

Since 1980s, Chinese PV market started its development with the supporting of the state, which made PV systems utilized and developed in industrial fields and rural areas in China. Application areas include microwave relay stations, anti-corrosion catholic protection, rural carrier wave telephone, the village power supply systems and home systems, etc., which laid the market foundation for PV technology applications in China.

Being promoted by the government, Chinese PV market has developed rapidly, the state has implemented successively the national PV power programs such as the "Tibet Non-electricity County Development", "China Brightening Project", "Tibet Ali PV Program", "SDDX Project" and "State Power Development in Non-electricity Areas". During the 9th -11th 5-year plan period, a number of demonstration projects were carried out, such as urban grid-connected PV power and large-scale grid-connected PV desert station. The Chinese government also seeks international aided and international cooperation to carry out PV projects, which have promoted the PV application in rural areas. By the end of 2008, the PV power installation capacity in China reached 140MW [1].

In Fig5-1[1], the development status of the PV system annual installation capacity (blue) and accumulative installation capacity (red) in China since 1990 are shown. The peak of the middle blue bars is an increase during 2002-2003, the implementation duration of SDDX project.



Year	1990	1995	2000	2002	2004	2005	2006	2007	2008
Installation Capacity(MWp)	0.5	1.55	3.3	20.3	10	5	10	20	40
Accumulative Installation Capacity(MWp)	1.78	6.63	19	45	65	70	80	100	140

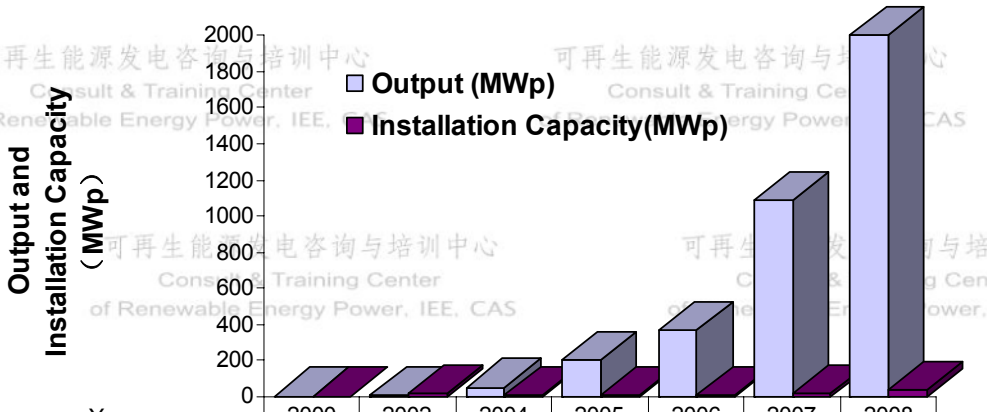
Fig 5-1 Chinese PV system annual installation capacity and accumulative installation capacity in 1990-2008[1]

2. Chinese PV market characteristic

Generally, Chinese PV market has developed steadily with the time and exhibits the characteristics as followings,

1) Chinese domestic PV market lags much behind the PV industry in China[1]

Chinese PV industry has developed fastest in the world. The total output in China reached 1,088MWp in 2007, which accounted for 27.2% of that in the World. China became the largest solar cell producing country in the world, and it also ranked the first in the world in 2008. But Chinese domestic PV market developed slowly and the great imbalance does exist between the PV industry and the market. In 2007, the PV system installation capacity was 20MWp, only accounting for 1.84% of the total PV module production in China. In 2008, the installation capacity was about 40MWp, occupying 2% of the total production. The annual production and annual installation capacity are shown in Fig 5-2.



Year	2000	2002	2004	2005	2006	2007	2008
Output (MWp)	3.3	10	50	200	370	1088	2000
Installation Capacity(MWp)	3.3	20.3	10	5	10	20	40

Fig 5-2 Chinese solar cells production and annual installation capacity

2) Chinese domestic PV market lags much behind of the world[1]

Though the annual growth rate of Chinese solar cell production has been much beyond the global level, the Chinese domestic PV market developing lags much behind of the international. In 2006, Chinese solar cells production accounted 17.1% of that in the world; the Chinese domestic PV market only accounted 0.57% of that in the world. In 2008, Chinese solar cells production accounted 31.3% of the world, but Chinese domestic PV market only accounted 0.71% of that in the world. By the end of 2008, Chinese PV systems installed capacity accumulatively reached 140MWp, less than 1% of the total in the world (about 18GWp) as shown in Tab 5-1.

Tab 5-1 Annual solar cells production and market percentage in China and the world in 2003-2007

Year		2003	2004	2005	2006	2007	2008
China	Annual production (MWp)	12	50	143	438	1,088	2,000
	Annual growth rate（%）	100	317	186	206	148	84
World	Annual production （MWp）	744	1,200	1,760	2,560	4,000	6,400
	Annual growth rate（%）	32.5	61	47	45	56	60
Chinese solar cells production percentage in the world (%)		1.6	4.2	8.1	17.1	27.2	31.3
Chinese PV market percentage in the world PV market（%）		0.5	0.3	0.3	0.57	0.71	0.71

3) Chinese domestic PV applications are mainly in off-grid power, and the international is in grid-connected power[1]

Chinese PV market is mainly in application of the off-grid power generation, and is in the stand alone power system, including: rural electrification, communications, industrial applications and solar commercial power supply products and so on. The proportion of grid-connected PV power applications is very small. By the end of 2008, the accumulative installation capacity was 140MW in China; and the grid-connected PV market accounted for only 20%. The PV market distribution is shown in Fig 5-4.

Tab 5-2 Chinese accumulative installation capacity and the PV market distribution in recent years

Market	Accumulative installation capacity（MWp)			Accumulative market percentage （%）		
Year	2006	2007	2008	2006	2007	2008
Rural Electrification	33	42	48	41.3	42	34.3
Communication & Industrial app	27	30	35	33.8	30	25
PV Products	16	22	30	20	22	21.4
Urban Grid-Connected	3.8	5.6	26.1	4.8	5.6	18.6
Grid-Connected in Open Fields	0.2	0.4	0.9	0.3	0.4	0.6
Total	80	100	140	100	100	100

Different from the Chinese PV market, the world grid-connected power market percentage was above 50% early in 2000. By the end of 2007, gird-connected PV accumulative market percentage of PV power system was beyond 80% and became the main applications in the global PV market, as shown in Tab 5-3 and Fig 5-3.

Tab 5-3 Comparison of grid-connected and off-grid in the world in 2000-2007

Year		2000	2001	2002	2003	2004	2005	2006	2007	Total
Grid-connected	Installation Capacity（MWp）	124.8	198.4	306	476	891	1252	1543	2600	7566.2
	Annual growth rate (%)		59.0	54.2	55.6	87.2	40.5	23.2	68.5	
Off-grid	Installation Capacity（MWp）	115.2	121.6	146	134	195	198	207	226	1747.8
	Annual growth rate (%)		5.6	20.1	-8.2	45.5	1.5	4.5	9.2	
Total	Installation capacity（MWp）	240	320	450	610	1086	1450	1750	2826	9312
	Annual growth rate (%)	20	33.3	40.6	35.6	78.0	33.5	20.7	61.5	
Percentage of the grid-connected(%)		52	62	68	78.03	82.04	86.34	88.17	92	81.25

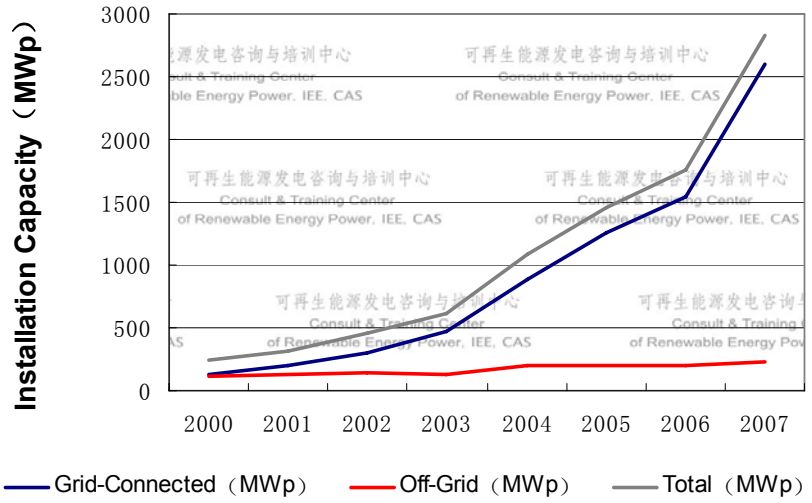


Fig 5-3 Global PV power market development

4) At present Chinese domestic PV market mainly financed by the government

At present, Chinese domestic PV market consists of two parts. On the one hand, the national demonstration projects, people's livelihood projects, and international cooperation projects, such as "Tibet Non-electricity County Development", "SDDX Project", and "Brightening Project", and other remote and rural areas PV power supply projects. Those projects were the most important markets and applications in China, along with a small amount technology demonstration projects such as street lamps, advertisement boards, and lawn lamp and so on. Most of these standalone PV stations and grid-connected PV stations are funded mostly by the Chinese government, foreign governments and international organizations. On the other hand, Chinese PV market also includes the power supply source such as the non-electricity

area communications, satellite signal transmission and receiving, and the catholic protection systems of oil and gas pipeline; The PV projects were commercially based on the markets and implemented by large state-owned enterprises. All of these projects funded by government and promoted by national policies directly impact the development of Chinese PV market.

For example, in the project funded by National Development and Reform Commission (NDRC) / World Bank (WB) / Global Environment Facility (GEF) China Renewable Energy Development Project (REDP), a total number of 300,000-350,000 sets of home solar PV power systems (SHS) were installed, with installation capacity of 10MWp during the implementation period of 2002-2007.

Since 2002, “SDDX” project installation capacity reached 19.6MWp. Total of the above projects installation capacity were nearly 30MWp, accounts for 30% of the accumulative installation capacity in 2007. By implementing the “SDDX” project, Chinese PV market increased some suddenly in 2002-2003 and dropped back significantly in 2004-2005. Although the “*China Renewable Energy Promotion Law*” being put into force in 2006 has some promoting effects on the Chinese PV market, for the absence of implementation details for PV power, the development of PV market was still very slowly in China. In the past two years, with being funded by the local governments in Beijing and the investors, the standalone PV systems have been built such as rural roads lighting projects in suburban areas. And with being promoted by “Green Olympic Concept” in Beijing Olympic Game 2008, a number of urban grid-connected PV demonstration systems have been built and the installation capacity of Chinese PV market came up obviously, as shown Fig 5-1.

5.2 High cost of PV module leading PV systems expensiveness

PV module is the most crucial part in PV power system. The proportion of PV module cost varied differently in different types of PV systems such as off-grid, grid-connected, PV roof, PV lighting and so on. For example, in recent years, PV module accounted for about 40-50% of the total investment in off-grid PV systems. PV module even accounted for 70-80% of the total investment in grid-connected systems. In the PV roof and PV lighting systems, PV module accounted for about 30-40% of the total investment. Although the prices of the other parts in the system have a greater impact on the cost as well, the price of PV module is the main factor in the cost of PV power system.

PV power industry chain not only includes the manufactures a variety of equipments and parts, but also includes the construction of PV power system and the application. The production of high purity poly-crystalline Si materials is a key link in the chain of PV module production. The core technology “Modified Siemens Arts and Craft” was controlled by few American, German, and Japanese companies in

monopoly and the price of PV module was kept high for a long time, which has been set up a high-cost threshold for PV large-scale application.

In recent years, domestic investment on silicon ingots (silicon bars) and wafers became up-surging unprecedentedly. With many years' efforts of Chinese PV industry, some Chinese enterprises have mastered the key technology of "Modified Siemens Arts and Craft" and held the independent intellectual property of the core technologies of high-purity silicon production in the utilization of raw material, pollution control, and energy consumption, which reached the international advanced level. The price of PV module was expected to reduce substantially.

5.3 Large-scale PV Grid-connected experiment is expected to be launched

1. Chinese grid-connected PV technology lags behind the internationally level

If grid-connected PV power wants to hold a position in electric power field and play a role, it is necessary for PV grid-connected to comply with the provisions and requirements of the current electric power system, in order to ensure the power quality and security of system operation.

The Chinese Government has paid more emphasis on the PV power technology. Early in 8th 5-year and 9th 5-year plan in China, Chinese Ministry of Science and Technology (MOST) has deployed the sciences and technology research on grid-connected PV power, controller, and inverter used in large-scale PV power station, and obtained the periodical results. During the 10th 5-year plan, the grid-connected PV technology was arranged as the key and important research direction. MOST strengthened the research on the design of grid-connected PV power system, key equipments and BIPV/BAPV. All of these accelerated the development of grid-connected PV power technology. At present, Chinese grid-connected system technology is basically mature, and the key technical performances are in full compliance with requirements and regulations of the electric grid system.

Chinese PV power system still have much to be improved, especially the system connecting criterion for PV power has not been made. Although some R&D and scientific projects of grid-connected power generation technology were implemented in China, the stability, reliability of grid connected PV power system shall be researched further in depth, Because solar energy has the characteristics of randomicity, non-continuity and dispersity, it is very necessary to cooperate closely with the electric power departments to solve the technical issues, power dispatch and management issues during spreading the PV grid-connected power, so as to ensure the security of electric power system and reliable power supply. Provided that the

grid accepts the PV power and fully purchases the electricity at the feed-in tariff in the principle of “reasonable cost plus reasonable profit”, the common effort from government, the PV industry, the power generation companies, and users shall be made in order to promote the stability and sustainable development of PV market.

2. Grid-connected PV system technology has not experienced the practical test in certain scale

Grid-connected PV technology is not only the key to the PV power to be connected to the electric power system, but also is the fastest growing technology in renewable energy. Grid-connected PV power has become the dominant market in the world. In Europe, the grid-connected PV systems accounted for more than 95% in 2006-2007, which shows that PV power will play more and more important alternative role in future energy sector.

Grid-connected PV power is divided into two major parts. The first one is the distributed grid-connected PV systems such as PV roof and BIPV with the capacities between decades to hundreds of kW, and the grid-connected point are at the end of the grid. The second one is the PV power plants in open fields, which are centralized grid-connected PV systems installed on open fields such as in the Gobi desert; the PV system can connect directly into the high voltage grid with the capacity of MW level and above. At present, China has built hundreds of grid-connected PV systems, and the installation capacity ranged from kW level to MW level, of which there are more than sixty grid-connected solar PV systems installed, with over 5 kW.

Generally, the grid-connected PV applications in China started late with a small scale, and also has not experienced the practical tests in certain scale. The impact issues on the power system have not been systematically studied, and the safety, electrical power distribution, operation and management issues of grid, to which large scale PV power is connected, shall be researched further. All of the grid-connected PV projects are still in the demonstration period in China. No real practical testing and demonstration research has been carried out, and also there is not the perfect system of quality standards. The complete pilot grid-connected PV power projects have not experienced test and deep research in a practical and economical sense, which are summarized here:

- The practical MW-level grid-connected testing and validating have not been implemented and relevant technology, operational management and economic benefit need to be further practiced and explored.
- Most grid-connected PV roof systems are the pilot projects, and most of which are the political projects, there is no the practical solutions to the grid-connected technology, management and economic model. No breakthrough has been made in terms of the management system for the

scale applications.

- Some BIPV projects are mainly built for the imaging and disseminating purpose, and have not come to the stage with sound technical design standards and supporting policies for economic operations, and just played very limited role in promoting the technology.

5.4 PV power policies are lack of the maneuverability

PV market needed to be driven by the complete and supportive rules, regulations and policies

Under the double pressures from the energy and the environmental deterioration, with enormous technological progress of the PV industry, since the late half of 1980s, the world PV industry and PV market entered the rapid development times. The gradually improved regulations and policies are the powerful driving force to promote the development. In 2004, the German government implemented the amended "*Feed in Tariff Laws*", which greatly promoted PV industry in Germany.

Only reliance on technological improvement hardly integrates PV power into the power system[1]

The development experience of PV industry and research shows that the PV power cost is still 8-10 times of conventional power generation(coal or hydropower) if the price of PV module maintains US$3 /Wp. According to the prediction, only relying on the technological advance (including each country relevant science and technology supporting), and without stimulus policy, it will be in 2050 that PV power cost can close to or reach the level of the conventional power generation . If PV power cost can compete with conventional power generation in 2020, only the technological progress is far insufficient.

Only reliance on the governmental fund hardly drives the PV market large scale and sustainable development[1]

So far, most of Chinese PV power projects were financed and implemented by governments, and partially were funded by Chinese, foreign governments and international cooperation. However, for most projects are the governmental act, market-oriented and business-oriented regulations and policies of construction, management, operation of PV power projects have not been made, and some provisions and requirements are not complete and not integrated. Although the PV power projects played positive role in Chinese PV market and PV power development, the positive effects are not long and lasting, without the function of booster. Therefore, the development of Chinese PV power and PV market is still slow.

With regard to off-grid PV power system, especially the SDDX program in 2002

organized by NDRC, which is the largest international investment in the world in the application of PV power technology to solve the problem of rural power supply, total investment of projects was RMB 4.7 billion, of which the investment of the wind-PV hybrid power supply system was RMB 1.6 billion and the installation capacity is about 19.6MWp. However, for no corresponding policies and regulations available, many troubles have occurred in the management and operational maintenance of SDDX power plants. Those problems not only influenced the sustainable development and long-term safe reliable operation of plants, but also influenced the implementation of the following projects, such as ”SDDC” and ”SDDH” program.

With regard to the grid-connected PV power, early in the 8th 5-year and 9th 5-year plan, China started to carry out the research on the key technology and equipment of grid-connected PV power. In the 11th 5-year, State Ministry of Science and Technology arranged five grid-connected MW-level demonstration projects through national Hi-tech program. In recent years, the local governments have built some large-scale grid-connected PV projects which funded by local governments and the local investors. Those projects include Chongming Island 1MWp PV roof power system in Shanghai, Lingang XinCheng 1.1MWp PV roof power system in Shanghai, 1.5MWp grid-connected PV power system in a five-star hotel in Baoding, 1.2MWp grid-connected PV system at airport and office building in Wuxi, 1.2MWp grid-connected PV power system at Culture Park in Longgang of Shenzhen, and so on. Those MW-level grid-connected PV power systems play a positive demonstration and driving role in application and development of grid-connected PV power in China, without the supporting policies and regulations for PV power commercial operation. These projects with various sizes are all the pilot projects promoted by governments; the no project was developed, and constructed and operated by project promoters totally in the manner of commercialization. For the sake of grid safety, the Grid Corp did not involve in such projects actively, but held a wait-and-see and passive attitude. It is no doubt that these issues have restricted the large-scale sustainable development of the Chinese PV market.

National legislation greatly drives PV market development[1]

The international PV market development history proved that only the maneuverable national laws, rules and regulations can drive the fast and healthy growth of the PV market, the simple policies are not effective. Since 1970s PV terrestrial application, U.S.A. has made a series of policies to encourage the development and utilization of PV power such as ”Million Solar Roof Plan”, ”PVUSA” and so on. In Japan, the implementation of government PV power subsidy policies started at 1974, which turned Japan into the largest solar cell producing country and the biggest PV market in the world (Germany surpassed Japan in 2006). However, no second country can imitate the Japanese practices because in many countries,

the state financial subsidy to PV industry can not be available or lasted forever, it may not only be queried by different aspects, but also lack of continuity in policies for the government completion of a term of office. Thus this approach has limitations. More than 30 years, many countries have taken dozens of incentive policies to promote renewable energy development, but the accomplishment was few. The only German government enacted “Feed-in Tariff Law” which drove the fast growth of its PV market and turning itself into the largest PV market and the second largest solar cell producer in the world. So far, more than 40 countries and regions imitated the German policies one after another to implement the own tariff law, such as Belgium, Greece, Italy, France, Spain, Portugal, Australia, Korea, India, California and so on.

Maneuverability have the roles in policy implementation

After “China Renewable Energy Promotion Law” issued in January 2006, China issued “*Trial Management Regulation on Renewable Energy Special Fund*”. Relevant administrations issued a series of policies and regulations to support renewable energy such as “*The Trial Management Measures of RE Power Pricing and Expenses Apportioning*”. These policies and regulations provide law basis and political guarantee for large-scale development of renewable energy and promoted Chinese PV power market effectively.

Relevant policies and regulations issued in recent years are as follows:

NDRC, “*Temporary Measures for the Implementation Details on “China Renewable Energy Promotion Law’”*, Apr, 2006.

NDRC, “*Temporary Measures on RE Tariff Add-in Revenue Adjustment and Distribution”* on January 11, 2007. (NDRC Pricing [2007] No.44)

The State Council General Office forwarded “*Energy Conservation Power Dispatch Policy*” on August 2, 2007 (SCGO [2007] No.53). The power generating units of solar energy and wind energy are the top-priority scheduled for power dispatching.

SERC issued “S*upervision Measures on that Grid Corporations fully Purchase RE Electricity*” in 2007(Being into force on Sep 1, 2007)

General Office of NDRC issued “*Notification on Requirements for the Large-Scale Grid-Connected PV Demonstration Power Plan”* On Nov 22, 2007. In the notice, the size of large-scale grid-connected PV demonstration power plant in Gobi desert shall be more than 5MWp and also stated the principle that feed-in tariff shall be determined by tender.

Formulated in the relevant documents, the late stage operation and maintenance subsidies of renewable energy off-grid power system are come from renewable energy tariff add-in, as same as RE grid-connected power.

From the above provisions of policies, Chinese RE power related laws, rules and regulations have been basically in place and were applicable to PV power. But the *"One thing, one discuss"* policy for PV power lacks of viable details and the "*China Renewable Energy Promotion Law"* is difficult to play a deserved significant role in promoting the development of Chinese PV market. So far, neither the domestic PV power project adopts feed-in tariff to implement the provisions of the "*Reasonable Cost Plus Reasonable Profit"* in the national regulation, nor the project promoter manages the PV projects in full commercial mode.

- Lack of the supportive "PV Grid-Connected Power Tariff Regulation" which matches the article of "Whole grid averagely allocating" in "China RE Promotion Law", so that due to the high cost of PV power, it can not develop faster in the market principle in China.

- With regard to the power generation enterprises, absence of "PV Power Fixed Quota System, rules and laws" makes the power or the grid companies unenthusiastic and impedes the implementation of large- scale grid-connected PV power projects.

- On the aspects of PV power project investment and financing, lack of the specific requirements and rules such as tax derating, interest payment discount and the favorable policies and feasible tariff subsidy rules and procedures, which are both the barriers for large scale PV grid connected power in a commercial manner.

- Lack of PV power project supervision and evaluation mechanisms and incentive policies, rules and regulations leads to the insufficient legal basis for PV power development.

5.5 Technological standards, accreditation system, and quality assurance system

1. Relevant technological standards and criteria are incomplete

1) PV products Technology standards

With China joining WTO and the rapid development and enlargement of PV industry, PV technical standards play an increasingly important role in the development of PV technology, PV projects, and PV commercial activities in China. PV technical standards play an important role in healthy development of the PV market. Early in 1987 the National Committee of Solar PV System Standardization and Technology was established, in charge of the national solar PV system standardizing.

Chinese PV technical standards are divided into the followings, according to the components and performance of PV power supply system: terminology, solar cell, non-concentrating module, system (off-grid system and grid-connected system),

quality accreditation and accreditation, BOS (balance) equipment, concentration module and testing, task-specific as show in Tab 5-4.

Tab 5-4 Standard system of Chinese solar PV power

Type	Tasks
1) Terminology	To draft standards for terminology.
2) Solar cell	To draft national standards and industrial standards for solar cell.
3) Non-concentrating PV module	To draft national standards and industrial standards for non-concentrating solar power module in terrestrial PV systems.
4) System(off-grid, grid-connected system)	To draft national standards and industrial standards for design, structure, installation, test, operation, maintenance and safety for PV system equipments
5) Quality accreditation and appraisal	To draft the national standards and industrial standards for quality accreditation and evaluation of solar PV system equipments and components
6) BOS (balance) equipment	To draft national standards and industrial standards for BOS equipments (storage battery, charge controller, inverter, etc.)
7) Concentrating solar power module	To draft national standards and industrial standards for concentrator solar power module in terrestrial PV systems
8) Testing	To draft national standards and industrial standards for measuring methods and measuring equipments of solar cell, PV module and PV systems.

2) Current national standards related to PV products

In the 1990's, the Chinese standard system of solar PV energy systems was formulated. With the globalization, the Chinese PV standards are getting lined to the international standard system; the Chinese standards gradually converted from IEC standards. In the standards published, there are 18 Chinese standards equivalent to IEC standards. China is a member country of the IEC, as the PV industry large country, two Chinese experts have joined the workgroups of the IEC to formulate new international standards. Chinese standards basically equalize the international general standards.

China has totally published 41 PV technology standards, including 31 national standards, 10 industry standards, the specific titles and code number are shown in references [1].

3) Lack of compulsory standards on grid connected PV power

The majority of PV standards published were PV product technical standards. However, the PV standards and norms regularizing PV power quality and performance and directly affecting PV market are not comprehensive, and lot of items of PV power are also absent. In particular the related standards and technical norms of the large-scale grid-connected PV power plants are blank, which seriously

affect the development of Chinese PV market in a large scale. Among the above 41 PV standards, 30 standards are related to solar cells and PV module, and only three standards directly related to grid-connected PV power system.

In addition, the schedule of publication of national standards is too slow to meet the rapid PV market demands. At present, the speed of PV standards publicity in the world has been accelerated. In particular, many new PV systems technical standards have been publicised over the past years. However, due to the limitation of Chinese standard publication quantity each year, the completed standards often are publicised slowly and lately. In Tab 5-5 is shown the four standards of grid-connected PV system.

Chinese PV standards are seriously lack of compulsoriness and authoritativeness, which also impeded the implementation of the existing domestic PV standards and the PV market development. At present, a series of standards on PV module, grid-connecting inverter, and system connecting have been made and defined as recommended standards. None of them is mandatory. For example, the national standard "*PV System Grid Connecting Characteristic GB/T20046-2006*", based on IEC617271:2004 version, in which the electricity quality of the grid-connected PV power system fully satisfies with the key requirements of the grid from the view of grid. In fact, the national standards for BIPV and large-scale Gobi desert PV power plants have been released as well. For those standards are not compulsory and not authoritative, and can not ensure the actual implementation. The Grid Corp. has not issued the appropriate technical and management standards and the management practices, which impacted the promotion of Chinese PV market in large scale.

Tab 5-5 List of PV tech standards being completed, to be publicised

Standards for solar cell and PV module	PV devices Part 10: Measurement of linearity
	Universal norms of terrestrial crystalline Si solar cell
	Security identification of PV module Part 2:Testing Method
a standard for PV BOS component	Technical demand and testing method of the special inverter of grid-connected PV power
8 standards for PV system	Technical norms of standalone PV system
	The characteristic performance of standalone PV system
	The standalone PV system –design verification
	Security norms of grid-connected PV power system
	Performance testing method of grid-connected PV system
IEC standards have been published, but have not been transformed into Chinese standards	The recommended small-scale renewable energy and its hybrid systems for rural electrification, including 12 parts:
	Part 1: Provision of rural electrification

Standards for solar cell and PV module	PV devices Part 10: Measurement of linearity
	Part 2: Requirement and scope of electrification system
	Part 3: Development and management of project
	Part 4: Selection and design of system
	Part 5: Security norms
	Part 6: Accreditation, operation, maintain and replacing
	Part 7: Technical norms: generator
	Part 8: Technical norms: storage battery and controller
	Part 9: Technical norms: integrated system.
	Part 10: Technical norms: energy sources management
	Part 11: Technical norms: grid-connected conditions
	Part 12: Others subject

2. Absence of authoritative accreditation systems and organizations

1) Accreditation of PV products has not started in China

The mandatory accreditation for PV industry has not been performed, for Chinese PV industry has not been involved with the issue of important security. The more and more strict PV product accreditation requirement in international market make Chinese PV product have to be accredited by the test institutions recognized by the importing countries, and only be accredited by the test institutions recognized by the importing countries, Chinese PV product can be exported overseas. Foreign organizations of inspection and accreditation not only obtain the brand and economic benefits, but also strengthened the own status. In return, the threshold of accreditation and inspection was enhanced further, and Chinese manufacturers have to accept unconditionally.

The authoritative accreditation mechanism is the basis of quality assurance, and the mandatory accreditation is also the general practice adopted in many countries. For example, grid-connected inverter and PV module can hardly sell in Europe without TUV accreditation (IEC 61646), and can not enter the U.S.A and Australian market without UL accreditation. The mutual accreditation with the international system has not been established, so overall PV product quality is difficult to be assured and impacts the Chinese PV industry and market development.

2) Domestic PV product test and accreditation organization authoritativeness

There are three major PV test constitutions in China: Tianjin Institute of Power Sources (the 18th Institute), Shanghai Institute of Space Power Sources (No. 811 Institute) and the Quality Test Centre of CAS for Solar PV and Wind Power Systems. “National Solar PV Products for Quality Supervision and Inspection Centre” is being built in Wuxi, which is responsible for quality testing, monitoring and quality accreditation of Chinese PV technology and the development of PV market in the

future.

For the limitation of the equipments and conditions, Chinese overall testing level does not compete with international level, and has not been recognized by the international. The domestic testing institutions are making efforts and cooperating with foreign famous testing institutions to perform international test comparisons, with the purpose that Chinese PV test is recognised by the international, and lay a foundation for the Chinese wisely testing and accreditation, and promote China to become the largest PV producing country as well as the largest market of PV applications. Fortunately, the newly established "*National Solar PV Products for Quality Supervision and Inspection Centre"* has been authorized to issue UL and TUV accreditation, which will promote the healthy development of Chinese PV market.

3) Domestic PV product accreditation mechanism needs to be established and improved

The large-scale product quality test was conducted for the pilot project of the "Brightness Project" sponsored by the NDRC in 2000. A technical expert group was organized, and a grading measure for quality testing of PV products was taken, which provided a favourable guarantee of the product quality for the owner enterprises in the provinces. Along with the "SDDX" project in 2002 and the "Commercialization of PV Products by the WB/REDP projects", the testing and quality supervision of PV products are being recognized more and more by owners and users.

In order to adapt to the situation of the rapid development of Chinese PV industry, to guarantee the healthy development of Chinese solar PV industry, and to meet the demand of national construction and end consumption, the project of "*Establishing China's Accreditation System for Solar Energy Photovoltaic Products*" was organized by NDRC/GEF/WB/REDP. The project executive agency, China General Accreditation Centre (CGC), held the workshop of project kick-off and implementation guideline of the "*Establishing Chinese Accreditation System for Solar Energy Photovoltaic Products*". The Solar Energy Photovoltaic Products Accreditation Technical Committee was established. The initial preparation for PV product accreditation was done, and the relevant accreditation documents and procedures were made as well. The authoritative agencies and the qualified testing labs can conduct PV product testing according to international standards or the standards of concerned countries. China has primarily the condition to accredit the PV products in the hardware resource.

3. Incomplete of quality assurance system and effective supervision and evaluation mechanism

1) Incomplete of reliable quality assurance system and effective supervision and evaluation mechanism

The quality assurance system is composed of project related laws, rules and regulations, mechanisms, standards and a series of quality standards. It can be divided into three parts: project management quality control, construction and operation quality control and quality control of power supply. The composition of system is shown in Fig 5-4.

(1) Project management quality control is an important part of the entire quality control chain during the implementation of the project. The main task is to establish a quality control system, establish a regulatory authority of quality control, rules for management, norms, requirements, operational management of system, as well as the rules, measures, regulations and requirements of safety in production for quality assurance of projects. First of all, the implementation procedures and steps of the projects should be standardized in scientific and regular concept.

(2) Construction quality control includes both construction management and construction quality. Construction quality control includes: 1) quality assurance of major equipments and products. 2) Construction quality of related construction works, properties of system and norms of design. 3) Construction and technical requirements for the project implementation. 4) Performance requirements and quality standards for construction, installation, commissioning, materials, equipment, etc.

(3) Power supply quality control includes the after-sales service, quality requirements for power supply, operational maintenance for equipments and regulations of general expenses collection and use during the operation of PV power. Determination of the operation & management mode of project and operation management of executive agencies are a prerequisite for quality control during the period of time of the power supply.

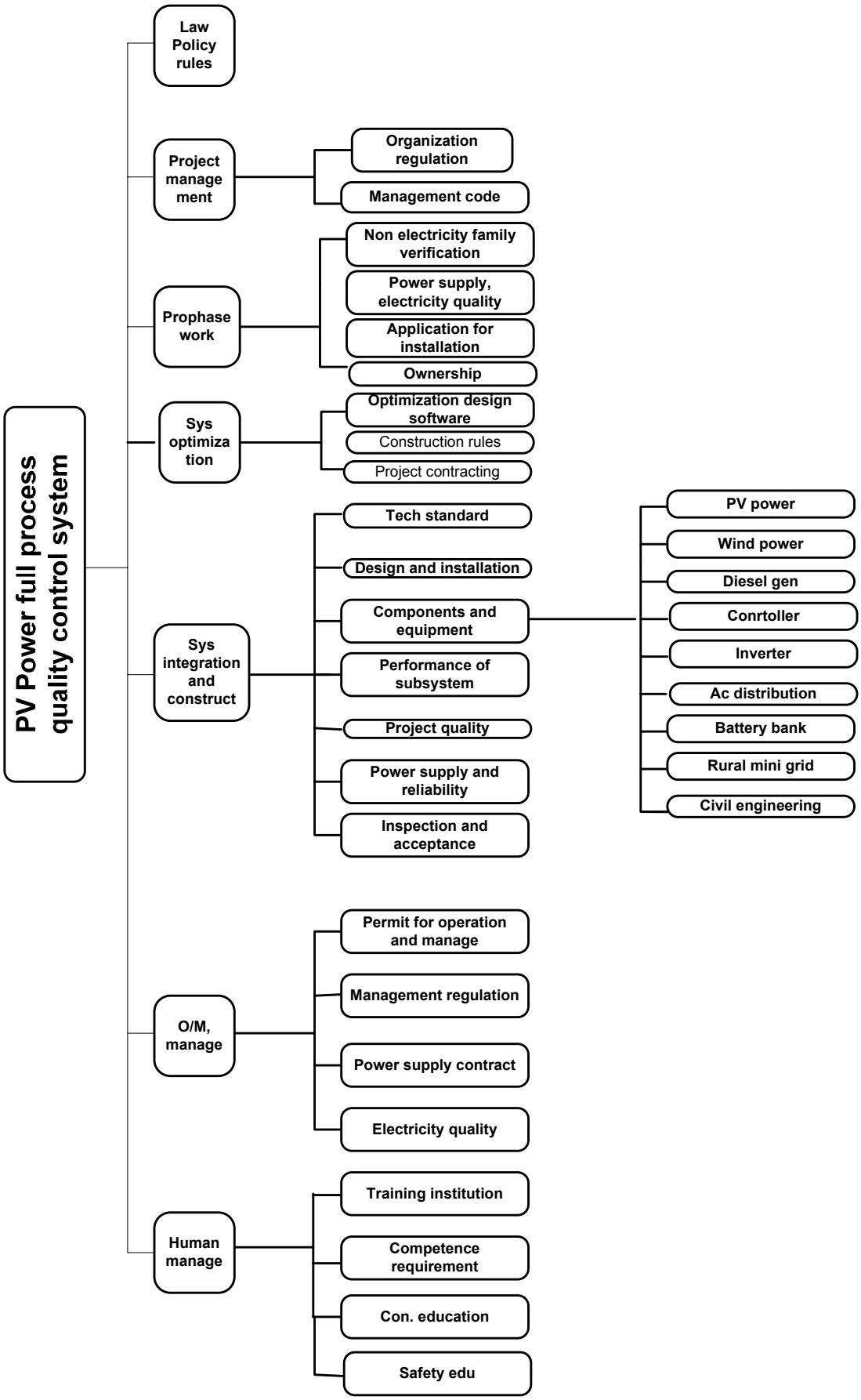


Fig 5-4 Off-grid rural PV power system project quality control system

2) Severe shortage in the quality control

So far, none of the Chinese PV power project is, in accordance with quality control system, to present, apply and be approved, construct, operate and manage. In a long time, Chinese off-grid PV power systems have focused on the system construction. As a result, severe links shortage or insufficiency in the quality control chain brought serious quality risks in the overall project implementation shown in Fig.5-4. For example, in the "SDDX" project preparation, the role of the project owners (responsible agency) was not paid enough stress in some regions and the responsibility for operation, maintenance and management were not clarified, which results in great difficulties for project transfer, maintenance and management. In accordance with the main contents of the quality control system, in the literature [6] quality assurance analysis for major Chinese village off-grid PV power projects such as "SDDX" projects, Japan aided NEDO projects and German KFW projects. In 24 sub-items of quality control, only KFW project have more than half of the 20 sub-items have the complete files and records and assessment score were 190 (most ideal scores is 240). And in "SDDX" projects, more than two thirds of the quality control sub-items were incomplete, so that the overall implementation of project had serious quality problems.

3) Absence of effective post-installation performance assessment and monitoring management mechanism

A complete and strict quality control system consists of two aspects, 1) rules and regulations and institutions, 2) supervision mechanism to ensure the implementation. PV power is special product. The product quality and after-sales service should have a special agreement to ensure the project quality in life. So far in China, no effective PV power project performance assessment system is established; project construction and operation monitoring mechanism have not been established yet, and there are no neutral and authoritative PV power advising, consulting institutions and system quality test and inspection and performance assessment institutions. Only relying on self-discipline of the dealers is not enough, it is lack of the regulation for the project management and operation and power supply service. Even regarding the REDP projects with strict management and regular spot checks and test samples, only the quality supervision on the production of power generation and power supply products was carries out, and without supervision on the operation of the equipments and the situation of power supply. All above has affected users' confidence in PV power and its reputation, also constrain the development of Chinese PV market.

5.6 Management and maintenance

1. The negative impact due to the problems of "SDDX Project" [9][10][11] [12]

Off-grid PV system always occupies the main PV market in China, which served

an important role in the remote no-electricity areas in China. According to the national development plan, “SDDC” project would have been launched since 2006. The original plan was to implement PV (or wind) power to solve the electricity supply issue in more than 16,000 no-electricity administration villages and 12,000 natural villages, supplying basic living power for four million families, with 16 million populations in no-electricity areas. The government mainly funded off-grid PV power system will still be the mainstream in Chinese PV market in the next few years.

The problems rose from construction and management in large scale Chinese rural PV projects have affected the full exertion and the sustainable operation of the PV power system. For example, the goals for the power supply systems are not clear; no specific standards are available; the project did not follow the principle of “acting according to the circumstances, multiple energy hybridization”; and the implementation procedure is not standardized. Those problems are not getting solved, especially the one regarding to the ownership of the project. The project management and normal maintenance can hardly be sustained, which slowed down the launching of “SDDC” project, which, as one of the major reasons, affects the developing of the Chinese PV industry.

2. Absence of the systematic PV management rule

On the national level, no specific PV management organization is established. Such management organization shall follow “*China Renewable Energy Promotion Law*”, conduct the unified planning, coordination, and management with the Chinese PV power, it is necessary to organize the expert team to make the strategic research on PV power, to study the global and domestic energy situation and the international trend for PV industry, to study the world PV power developing roadmap and the roadmap-making basis. Based on the study result, the Chinese PV power developing roadmap and the long term domestic PV development plan shall be made scientifically, so as to make the plan meet the needs of the Chinese energy sustainable development and environment protection.

The standard PV management codes have not been made in China, the management codes include, such as project application, preparation, construction, inspection and acceptance, operational maintenance, and management, quality control and supervision system etc. PV operation, maintenance, and management are the work associated with specialty, the policy, and the sociality, throughout the PV power life. Only with proper maintenance and management, the system will be able to supply power reliably and consistently. While ensuring the operation and management organizations, the powerful supporting of the laws and policies, and fund shall be ensured for the sustainable development of the project.

5.7 Capability building and education of talents

1. Status of PV power talents education in China[13][14]

1) Lack of relevant PV majors in colleges

Various education institutions (including universities, colleges and vocational schools) have not held the RE power and power supply courses and majors. Although some universities and research institutions are training the special senior talents of the renewable energy, only few courses belong to the education of the academic degree, such as the renewable energy specialty established in 2007, focusing the training of the wind power talents, in North China Electric Power University. The first PV major approved by the Ministry of Education, “PV material process and application technology major”, was offered in Xinyu College in Jiangxi Province on Sep.1, 2008. “Solar PV College” in Nanchang University was offered on Oct. 6, 2008.

2) No standing national level PV training institutions

In the past more than 20 years, Chinese PV industry had made great progress, but the long term training mechanism has not been set up at all. So far, none of the national level renewable energy training institutions has been established. Although some training facilities established by few relevant PV enterprises and departments offer training course for PV power, without the standard field, equipments, textbooks and teachers, they are not the specialized training institutions. No unified standards and requirements are available, and therefore the training can not meet the development of PV power and PV industry. With regard to the operation and maintenance staff, which is very important for the PV power system sustainable operation, the labor department have not set “PV operation and maintenance” to be an occupational title, and without the professional training schools and colleges for the PV operation and maintenance personnel and certificate system of professional skill, the professional qualities of the practitioner can hardly be assured.

3) The scale and effect of the few training courses are very limited

In order to support the some international aided projects, national and local projects, some training courses had been offered. However, the scale is small and effect is not obvious. The training did not range over broad fields, training way is not flexible, and the training books, with variety of contents, goals, level of the trainees, are very few. For example, in the past, the renewable energy training programs focused on the power generation and power supply, but no training was held for renewable energy power related personnel, such as official, manager, economist, and investor. Moreover, the training based on the general people in order to disseminate the knowledge of PV power is not offered.

2. PV talents insufficiency severely restricted the rapid and sustainable

development for the industry

For a long time, PV specialty for the PV talents education has not been set in China. So far, the researchers, designers, and personnel of production and construction in PV field are transferred from that of the semi-conductor and Si materials, and other no-PV industry in early time of China.

In recent years, Chinese PV industry experienced jumping development, and the technical level of main solar cell producers had been leading the world. The rapid expansion of the PV industry results in the shortage of the human resources. Many enterprises are lack of innovative abilities and the self-owned technologies; the big difference does exist in R&D and technology level between the Chinese and the international advanced level, especially in the area of thin film cells and the low cost cell production. So far, China does not have the large scale producing ability, with possessing the independent intelligent property in PV industry.

3. Lower quality of the O/M personnel of off-grid PV power system [15] [16]

The quality, knowledge, and the skill training of the PV power station personnel are the key factor in sustainable operation of the PV power system, which also affects the social reputation and the sustainable development for Chinese PV industry.

In remote rural areas, the round one thousand PV power plants, especially “SDDX” project and “KFW Sino-German Financial Cooperation project”, had been built and supplied power to the residents. All the station operators had been trained by the SDDX project system integrators at the beginning of the project construction, with certain amount of national and local governmental funds. However, the quality is not enough for the job of the operational technicians and managers. The knowledge of the trainees can hardly qualify the jobs, with the potential risks for the sustainable and normal operation of the power plants.

5.8 Analysis of relevant issues

1. PV industry energy consumption and energy recovery cycle

In the process of PV module, three steps including high purified poly-crystalline Si, ingots/wafers, and solar cell manufacturing consume higher energy and a mount of material. Because the technical and industrial levels for different factories are not same, the energy and material consumption in different stages varies greatly. Industrial Si, also called metallurgical grade Si, is with 99% purity. The purification process consumes 12-14KWh/kg energy. In China, the production of poly-crystalline silicon is mainly adopting “Modified Siemens Art and Craft”; the consumable materials include industrial Si, hydrogen and chlorine, etc. The energy consumption of deoxidization is about 80-200KWh/kg and the integrated energy consumption is

about 127-250kWh/kg. Ingot/wafer consumes more raw materials, such as quartz pot, glass, steel wire, silicon carbide, nitrogen and helium gas etc. The whole process consumes about 550-820kWh/kWp energy. many kinds of material is used in solar cell production, which consumes electrode print ribbon, nitrogen, oxygen, fluoride, sodium hydroxide, and washing solution etc. The process consumes about 200-250kWh.kWp energy. The materials of PV module encapsulation are the low iron glass, EVA, frames (aluminum), copper, tin, nickel, and packaging board etc. The energy consumption is about 50-150 kWh/kWp. The balancing components include controller, inverter etc. Here, the production of controller and inverter are mainly taken into consideration. The energy consumption is about 150-200kWh/kWp. The energy consumption for each stage is shown in Tab 5-6; the overall average energy consumption is 3,080kWh/kWp.

Tab 5-6 PV system manufacture each stage energy consumption

Manufacturing stage	Energy consumption （kWh/kWp）	Average energy consumption （kWh/kWp）	Percentage（%）
Industry Si (Metallurgical Si）	170~200	185	6.01
High purity Poly-crystalline Si	1,370~2,050	1,710	55.52
Ingot and wafer	550~820	685	22.24
Solar cell	200~250	225	7.31
PV module encapsulation	50~150	100	3.25
PV system	150~200	175	5.68
Total		3,080	100

Main material used in PV system production is hydrogen, chlorine, Silicon carbide, silver, aluminum ingot, aluminum frame, low-steel glass and packaging board. Corresponding energy consumption of used material is detailed in Tab 5-7 [24] and the overall energy consumption is 737kWh/kWp.

Tab 5-7 PV system main consumable material energy consumption

	consumable material consumption（kg /kWp）	consumable material unit energy consumption	consumable material energy consumption	
			kgce /kWp	kWh /kWp
H_2	1.76m^3/ kWp	5kWh / m^3		88
Cl_2	16.43	2kWh /kg		33
Silicon carbide	19.17	17.2 kWh /kg		330
Silver	0.735	1.561kgce /kg	1.2	3
Alumina ingot	1.82	5.704kgce /kg	10.4	28
Cell	0.42			
Inverter	1.4			
Alumina alloy frame	21	7.125kgce /kg	149.6	121
EVA	8	n.a	n.a	
Low iron glass	82	0.46kgce /kg	37.7	102
Package board	8.75	1.35kgce /kg	11.8	32
Total				737

Note: kgce-kg coal equivalent.

Without regarding to energy consumption of PV system installation, operation and equipment recycle, the overall energy consumption of PV system production in all life is the sum of producing energy consumption: 3,080kWh/kWp and the consumable material energy consumption:737kWh/kWp; so total energy consumption in PV system life cycles is 3,817kWh/kWp.

The energy recovery cycle definition: is all the energy consumption in life divided by the average energy output of the PV power system. It is how many years that PV power system can recover the energy consumed, it is obvious that the shorter the energy recovery cycle, the better the system.

Electricity generation of the PV power system is the system energy output, so energy recovery cycle of PV power system is determined by annual electricity generation and production energy consumption. The power generation is determined mainly by the local solar resource, operation modes and the efficiency in different links. Herein, the energy recovery cycle of the grid-connected PV system is calculated mainly.

The efficiency calculation of the PV grid-connected system needs to consider the efficiency of the individual components and the system operation. Comprehensive efficiency of PV grid-connected system in open field is around 80 %, fundamentally without the loss of orientation.

Solar energy resource is the main contribution to the annual electricity

generation and of the energy recovery cycle of PV grid-connection. Tab 5-8 shows the energy recovery cycle of the same configuration PV grid-connected power system in Beijing, Lhasa, shanghai and Chengdu. Due to the difference of solar energy resource, energy recovery cycle in four cities varies greatly. While the energy recovery cycle of PV grid-connected power system is 1.97 years in Lhasa, and 4.1 years in Chengdu.

Tab 5-8 the energy recovery cycle in different area

	Beijing	Lasha	Shanghai	Chengdu
The energy consumption in full life, kWh/kWp	3,817	3,817	3,817	3,817
Horizontal annual irradiation, (kWh/m^2)	1,561	2,191	1,314	1,053
Incline annual irradiation, (kWh/m^2)	1,748	2,453	1,445	1,180
PV power system yearly power generation (kWh/kWp)	1,381	1,938	1,142	931
Energy recovery cycle, years	2.76	1.97	3.34	4.10

According to the research in Holland, United States and Switzerland, the energy recovery cycle of current PV grid-connected power system is 1.5~6.9 years, much shorter than the duration of operation of 25~30 years or even longer. For example, case study in 41 cities of 26 OECD countries made by international energy agency shows the shortest energy recovery cycle of poly-crystalline silicon PV power system with best installation inclination is 1.6 years (in Bosi of Australia) and longest time is 3.3 years in (Iderberge of Britain), energy recovery cycle of vertical curtain wall is 2.7 years in Bosi Australia and 4.7 years in Buressul, Belguim (IEA-PVPSTask10，May 2006).

It shall be noted that energy recovery cycle of PV power system is a dynamic and changing concept, i.e. it become shorter and shorter with the application enlargement, industry and technology improvement. For example, in the late 1980s, the energy recovery cycle of crystalline silicon PV power was 5~10 years. In the mid of 1990s, it was 3~8 years. At the begning of this century, it shortens to 2.5~6 years, and at present it is 2~5 years. With the continual development of PV technology and industry, energy recovery cycle of PV power system gradually shortens, and it will reach 1~2 years in the future.

2. Pollution protection

1) As the poly-crystalline silicon production increases in China, environment issues for the by-product of $SiCl_4$ became highlighted. If $SiCl_4$ of strong causticity and toxicity is not recycled, the environmental risk will be huge.
2) Poly-crystalline silicon purification technology is with higher technology threshold, large investment, and controlled by ten manufacturers in United

States, Japan and Germany. The foreign poly-crystalline silicon manufactures block the techniques of advanced poly-crystalline silicon production. Some domestic enterprisers blindly launched the project of poly-crystalline silicon purification, without installing the recycling system, at the cost of high energy consumption, environmental pollution, and ecological destruction. However, majority of the poly-crystalline silicon manufactures have realized the zone emission and clean production through tail gas recovery, material recycling and comprehensively utilization. There is no impassable technology barrier.

3) CO_2 is the biggest polluting source in the process of converting silica sand to metallurgical grade silicon. However, only 2% of annual 120 million tons metallurgical grade silicon production in China is used in semiconductor field including micro-electronics and solar energy; the majority is used as an additive in iron and steel industry, aluminum alloy industry and organic silicon industry.
4) $SiCl_4$ is an important byproduct of “Modified Siemens Arts and Crafts” of the high purity silicon production by $SiCl_3$. If closed production line can be used, 98% $SiCl_4$ can be reused, not only reduce energy consumption, but avoid pollution. Otherwise, large amount of must be treated, generally, fabricated as white carbon black. If $SICl_4$ can not be treated properly, the environment will face risk. It should be noted that the complete and widely known techniques have been used in micro electronics industry for silicon purification for a long time. If pollutants are properly treated, environment pollution could be avoided.
5) Firstly, during the process of poly-crystalline silicon casting and direct pulling mono-crystalline silicon, acid and alkali solution are used in solar cell production in corroding and washing, such as HF, HNO_3, NaOH. Comprehensively treatments are needed before discharging the waste. Secondly, in the process of washing and corroding, corrosive gases generated from the reaction of the acid and alkali solutions and silicon must be treated before discharge. Thirdly, silicon power produced in process of ingot cutting by machine, which could not be recycled totally, the cutting liquid with silicon power should be treated before discharging. It should be noted that the complete and widely known techniques have been used in micro electronics industry for silicon purification for a long time. If pollutants are properly treated, environment pollution could be avoided.
6) Firstly, acid and alkali solution used in solar cell production in corroding and washing, such as HF, HNO_3, NaOH, need to be comprehensively treated before discharging. Secondly, in the process of washing and corroding, corrosive gases generated from the reaction of the acid and alkali solutions

and silicon must be treated before discharge. In the end, the complete and widely known techniques have been used in micro electronics industry for silicon purification for a long time. If pollutants are properly treated, environment pollution could be avoided.

7) In PV module assembly, the waste liquid and gas hardly exist, the solid wastes does not pollute the environment.

3. Safety issue of PV grid-connected

National standard on the technology requirement of PV grid-connected has been established. The requirements of grid-connected PV power quality can refer to national standard GB/T20046-2006, named "*PV System Grid Interface Characteristics*". This standard mainly adopts articles of IEC61727:2004. From electrical grid view, this standard illustrates the following requirements for PV grid-connected system:

(1) Normal voltage range of the grid: PV grid-connected inverter must shut off within a very short time (general 0.5 second) as the grid voltage exceeds the operation condition.

(2) Normal frequency of the grid: PV grid-connected inverter must shut off within a short very time (general 0.5 second) as the grid frequency exceeds the operation condition.

(3) Flicker: flicker induced by PV system operation shouldn't go beyond the limitation of value of IEC61000-3-3 and IEC61000-3-5.

(4) DC injection: In the any operation condition, the injected DC from PV system to grid AC interface can not be more 1% than that of the output current of the inverter.

(5) Harmonic and wave form distortion: the PV system output should have lower current distortions to ensure no adverse effect on other equipments connected to utility grid. Total harmonic current distortions shall be less than 5% of the rated inverter output.

(6) Power factor: as the output exceed over the inverter rated output 50%, the lagging power factor shall be greater than 0.9. No confinement with the special design with the reactive power compensation.

(7) Counter islanding protection: PV system ceases to supply electricity to the grid, as grid is power off within 2 seconds, do as for prevent from getting electric shock accident.

Current technical level in China could meet the above mentioned technological indicator requirement. The technical standards continually improve and develop, especially in PV power, a new technology field; the foreign standards are often replaced and updated. Except for standard of IEC, other countries also established

the domestic PV power standards, such as Germany VDE126, Australia AS4777, United States UL1741, Spain RD1663, Italy DK5940 and UK G83/1. The requirements of these standards are similar and different only in the values. It should be noted that German standard VDE126-1-1 prescribes that PV grid-connected system must include the individual judging module for the counter island protection, which is the strictest one.

From the international large scale PV grid-connected application, PV power is more stable than wind system regarding to power output. At the same time, the power of single PV equipment is lower, so the failure of single PV equipment has little effect on the utility grid. However, lots of research needs to be done in order to avoid the problems as the large scale PV power system connects to the weak utility grid in the future. In general, PV system connected to single medium voltage level line is prone to control and greatly reduce the overspreading of the failure.

4. Bidding issue of large scale PV grid-connected project

Through many years of preparation, NEA launched Dunhuang 10MWp PV grid-connected tender. 50 companies bought tendering document and 18 of them officially bid, 5 of bidders are eliminated throughout the selection, 13 of bidders entered into the second round business tendering. In these 13 effective bidding documents, lowest PV grid-connected price is RMB 0.69 Yuan/kWh, and the highest one is RMB 1.92 Yuan/kWh, and most of them are around RMB1.4-1.6 Yuan/kWh. This bidding result make people review the saying that PV power have the price of RMB 3-4 /kWh and recall the event of the extreme low price of RMB 0.382 Yuan/kWh to win the bid at the beginning of Chinese wind power concession bidding.

Since 2002, China began to adopt feed-in tariff for wind power which is the modes of tendering price and approval price in parallel. In 2003, the first four batches wind power projects adopted concession bidding of “lowest bid will win”, and the enterpriser won bid through the extreme low price of RMB 0.382 Yuan/ kWh. After several adjustments on wind power concession bidding, in which the weight ratio of tariff is weakened and the weight ratio of technology and localization rate of components enhanced. In 2008, wind power bidding mode of “middle price won bid” was adopted in the fifth round concession bidding to avoid cut-throat low price competition, which was in favor of wind power tariff to come back to a reasonable level and promoted wind power industry development. Wind power concession bidding expanded the scale of wind power, attracted investment on wind power and assisted domestic wind power equipments manufacturers.

Currently, China has the conditions to spread PV power in a large scale. Tendering can be used to promote PV industry and PV market development, but lessons and experiences from wind power tendering shall be learned. A set of scientific tendering mechanism must be established to ensure a healthy, orderly and

sustainable development of PV industry.

5.9 Summary

1. The key factor impeding the large scale PV power is the expensive electricity cost. Although solar power has been greatly advocated by the state, the present conventional electricity is much cheaper than that of PV power, which is now less competitive. Incentive policy is still needed to foster the domestic PV market. Considerable difference still exists between thermal power cost and PV power, it is a worldwide issue.
2. Few foreign large companies control the key technology of poly-crystalline silicon purification and formed technology monopoly, which set a high cost threshold for domestic large scale PV power spreading. Over a period of time, the ever increasing high price of PV module caused the PV power system very expensive, it is the key constraint of PV development. Another reason for the high cost in PV power is the laggardness of fundamental facilities and equipments with low quality of the products. The manufacturing cost of domestic PV module is higher 10%~20% than that of international in general.
3. Chinese PV industry has gained obvious improvement in past five years, but overall competitiveness of PV industry chain is still weak, the weakness include: firstly, in spite of PV industry integrity, except for certain competitiveness of PV industry chain midstream; upstream and downstream of the PV industry chain are all weak in turn, raw and processed material for every chain that needed to be imported from international market partially. Secondly, important technology link of the PV industry chain is expecting a breakthrough, except for that of the solar cell and module assembly technology, which has certain advantage in Jiangsu, Hebei and Shanghai. A gap exists between domestic and international advanced technologies in silicon material purification and system integration; thirdly, the advantageous parts in PV industry chain is at the low end of the value chain, at present, the Si material purification, pulling, and wafer slicing are all at the high end of the value chain, with high profit; the mining of silica sand, wafer producing, and module encapsulation, belongs to the low end of the value chain, and the labor-intensive industry, with narrow margin of profit. The foreign labor intensive part in PV industry transfers to China, some PV enterprises took the chance in Jiangsu and Hebei, realized the rapid continuation and development.
4. PV grid-connected power is the mainstream of the PV market. In principle, the supportive policies for Chinese renewable energy power are in place for large scale PV grid-connected implementation. Due to the shortage of practical implementation rules aiming at PV power, the present high cost PV power can not develop rapidly in the market rule.

5. The issues of non-stability characteristic of the PV power, product quality and the management, especially the impact of uncertain PV grid-connected power quality on electrical grid, cause the doubts of electrical sector on PV power, and restrict the development of Chinese PV market in a large scale.
6. Establish the PV technology standard, strict quality qualification and quality assurance system, regulate management and maintenance, and all kinds, al levels of talent education will be capable to play important roles on healthy expanding PV market in large scale.
7. The force on promoting the incentive policies is far insufficient. Most effective and powerful measures for PV industry development are for government to make the incentive policies and the regulations with clear development target. Japan established the PV target of 4820MW for 2010 and developed research, demonstration, and high price purchasing plan are also laid out, so that Japan rapidly became the biggest country of PV industry. Although China launched "SDDX" and other electric power constructions in the west non-electrified counties, which promoted the PV development to some extent in China; at present, the incentive policies, such as subsidy policy, PV grid-connected policy and reasonable tariff policies haven't been made out. Some provinces have released the magnitude solar power development plan; however, it is far enough for launching Chinese domestic PV market, for the dramatically developing of Chinese PV industry.

References

[1] Zhao Yuwen, Wang Sicheng, etc. *Report on the Development of the Photovoltaic Industry in China (2006-2007)*, PMO of REDP, China Renewable Energy Association, Committee of Photovoltaic, May, 2008

[2] Wang Sicheng, *Research on Chinese PV power, Energy of China*, 2007 (2): 7-10

[3] Wang Sicheng, Dong Luying, etc. *Summary Report of Investigating on basic data of "SDDX" Projects Supported by UNDP*, Energy Research Institute of NDRC the baseline investigation experts team of "SDDX" projects, Dec 22, 2005

[4] NDRC Energy Institute, Beijing Jikedian RE Development Center, PMO of WB/REDP, *Investigation and Recommendations of "SDDX" Project*s, Dec 2, 2005

[5] IEE, CAS, *Investigation Report on Market Reputation and Product Quality of the*

Main Short-Listed Enterprises (Tibet, Xinjiang, Gansu, Qinghai) in REDP Projects, Analysis of Test Results and Quality Control Recommendations, Oct, 2004

[6] Ma Shenghong, Chen Dongbing, etc. *Study on quality control chain of villages off-grid PV power*. IEE, CAS, Sept, 2007

[7] NDRC/WB/GEF, *Presentation of the Projects Development of Chinese Renewable Energy*, PMO of REDP

[8] NDRC/WB/GEF, *Brief Reports on the Projects Development of Chinese Renewable Energy*, issue 12-25, PMO of REDP

[9] NDRC, "*Mid-Long term Development Plan for Renewable Energy*", Sept, 2007, www.sdpc.gov.cn

[10] NDRC, "*RE Development 11th Five Year Plan*"", www.sdpc.gov.cn，Mar 19, 2008

[11] Chinese *rural area electricity development outline*, Rural electrification Info Web, www.shp.com.cn

[12] IEE, CAS, *Sino-German Cooperation Program: Off-grid PV quality monitoring system*, Sep, 2007

[13] IEE, CAS, *Proposal on building training system for Chinese Renewable Energy*, Sept, 2005

[14] *First Chinese HEI Held PV major in Xinyu, JiangXi*, www.xinhuanet.com，Sep, 2, 2008

[15] Chen Dongbing, Ma Shenghong, et al, *Study and Analysis on rural off-grid PV operation system in villages (2) Survey and Analysis on PV power plant operator status in villag*e, Solar Energy, Sep 2007

[16] Zhang Yabin, Chen Guangming etc, *the survey on the PV and Wind Power hybrid power station operator*, Solar Energy, Mar, 2007

[17] Li Junfeng, Wang Sicheng, China PV development report 2007. China Environment Science Press.2007

[18] NDRC Energy Bureau, *Light of village brightness-"SDDX" project documents collection*. Knowledge Press, first press, 2006, Beijing

[19] Xia Aimin, Li Hua, Ma Shenghong, *In 2012, PV industry enter into phase of self growing - Global PV industry outlook*, China Construction overview: Sunlight Energy, issue 4, 2008, P45-48

[20] State Electrical Information web (www.sp.com.cn). *When renewable energy will*

play dominant role? Nov 7, 2007

[21] Zhao Yuwen, Wu Dacheng, et al, *Overview of Chinese PV industry and market development*, Solar Energy, issue 3, 2007, pp:7-10

[22] Wang Sicheng, *Implementation of renewable energy law in PV power, China Construction Overview*, Sunlight Energy, issue 1 2007, p12-13.

[23] Chen Dongbing, Ma Shenghong, et al, *Investigation and analysis on operation and application of stand alone village PV power plants – PV system user and system load investigation and analysis*, Solar Energy, Oct. 2007

[24] Hu Runqing, *Study on energy recovery cycle of poly-crystalline silicon PV grid-connected power in China*, solar energy, Jan, 2009

6. Research and proposals on the Incentive Policies to Accelerate the Domestic PV market and PV industry Development

6.1 Accelerate research for the technological breakthrough, improve and master the key technologies in PV industry

1. China shall have its own innovative crystalline Si purification technology [1]

The key to promote the application of PV power in a large scale is to lower the cost and price of solar cell and PV module. The production of poly-crystalline Si material is the bottleneck of the PV industry, which restricts the increasing of solar cell production, resulting in the high cost of the PV power ever since. Only the key technology and techniques of crystalline Si production and purification are mastered, the monopoly of the technology of the foreign supplier is broken; the Chinese situation of relying on importing high-purity poly-crystalline Si can be changed.

With many years endeavor of Chinese PV industry, some enterprises in China have already gained the critical technology of “Modified Siemens Arts and Crafts” and mastered the core technology of high purity Si production by self-innovating. The Chinese technology for high purity of Si production is advanced in the world, but still lags behind the most advanced level, especially on the aspects of raw material utilization, pollution protection, and energy consumption, the further improvement is needed. The state shall intensify the supporting strength on funding and personnel; keep the industry in the advanced level in technology, equipments, and techniques by the science and technology research for the breakthrough. By further upgrading the overall strength of the Chinese Si material purification, ensuring the quality of the product, enlarging the scale, and driving the price of PV module to the national level, so as to promote the sustainable development of PV power and market.

2. Intensify the supporting strength on the research and development of thin film cell [2][]3[]

1) The technology of thin film cell is getting matured in China

Thin film cells can be categorized into the three types of SI-based thin film cell, compound semiconductor thin film cell, and the dye sensitive photo-chemical cell by material.

The technique for thin film cell production is relatively simple and Si material consumption is very little. The price is mainly determined by the base materials, fabrication, and packaging etc, Si-based thin film have the obvious advantages over crystalline Si solar cells, with much more Si consumption. The shortage of Si material brings opportunity for the development of thin film cell technology and the market expansion, which is enough to counteract the shortcomings of low efficiency. The

technique in decreasing the optical attenuation of thin film cell efficiency is matured as well, and is already in the stage of practical and industrialized production.

2) Thin film cell is in the stage of practicality and industrialization, with rapid growth

The international production for mono-crystalline Si, poly-crystalline Si and thin film cell are shown in Tab 6-1, which shows the trend for thin film cell and crystalline Si cell. The percentage of thin film cell is increasing and its increasing rate is much higher than that of the crystalline Si cells.

Tab 6-1 worldwide solar cell production in 2002-2006

Unit：MWp

Year		2002	2003	2004	2005	2006*	2007
Production (MWp)	Overall production	536.8	747	1,201	1,792.9	2,561.7	4,000
	Crystalline Si cell	506.8	704	1,136	1,685.9	2,370.7	3,650
	Thin film cell	30	43	65	107	191	350
	Percentage of thin film cell	5.59%	5.76%	5.41%	5.97%	7.46%	8.75%
Annual growth rate (%)	Overall production	43.5	39.2	60.8	49.3	42.9	56.1
	Crystalline Si cell	49.9	38.9	61.4	48.4	40.6	54.0
	Thin film cell	-16.7	43.3	51.2	64.6	78.5	83.2

The industry developing situation in thin film cell is shown in Tab 6-2 and Fig 6-1, which shows that the Si-based thin film cell is the main stream in the thin film cell, accounting for 77.14% of total thin film cell production in 2007. Since 2004, the worldwide thin film cell industrialization came into the express way of development.

Tab 6-2 worldwide increasing of the thin film cell production in 2001-2007

Unit: MWp

Thin film cell	2001	2002	2003	2004	2005	2006	2007
a-Si,μc-Si	33.68	28.01	40.5	47.8	84	147	270
CIGS	0.7	0.3	0.5	3.6	2	4	6
CdTe	1.53	1.6	2	13.2	21	40	74
total	35.91	29.91	43	64.6	107	191	350

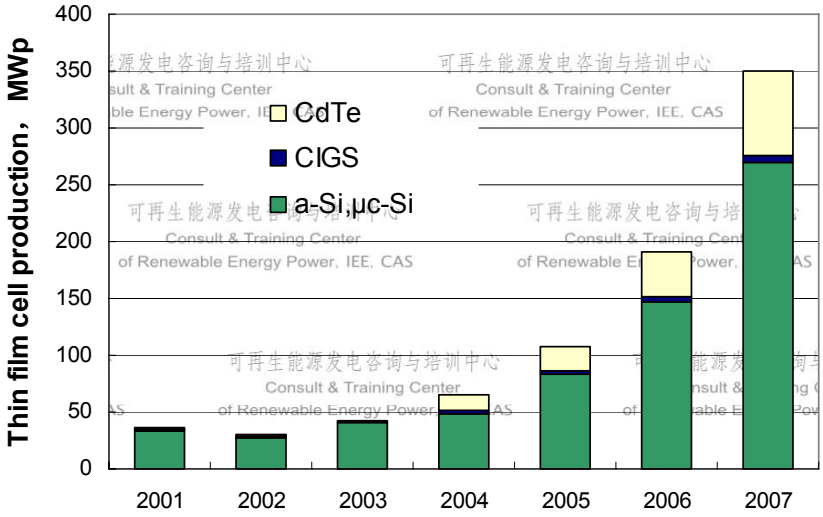


Fig 6-1 Thin film cell production increasing in the world

3) Powerfully promoting the development of thin film cell in China

China imported the producing technique for single junction a-Si cell in the late 1980s, and the industry of the A-Si cell has developed steadily. In recent years, thin film cell industry in China developed rapidly. By the end of 2008, there have been about 20 A-Si cell producers in China. The total production capacity reached 134.9MWp, the production of A-Si thin film cell was up to 37.9MWp in 2008, accounting for 19% of the overall solar cell production. See Tab 6-3.

Tab 6-3 the change of solar cell production in China

	2000	2001	2002	2003	2004	2005	2006	2007	2008
Overall production MWp	3	4.6	6	12	50	145.7	438	1,088	2,000
Crystalline Si cell MWP	2.4	3	4	10	44	137.7	426	1,059.7	1,962.1
Annual growth rate (%)		25.0	33.3	150.0	340.0	213.0	209.4	148.8	85.2
A–Si cell MWp	0.6	1.6	2	2	6	8	12	28.3	37.9
Annual growth rate (%)		166.7	25.0	0.0	200.0	33.3	50.0	135.8	33.9

Nowadays, the thin film cell has few disadvantages such as low efficiency, short life of span, lower market acceptance, and high risk in investment and others. The state shall increase the supporting strength on thin film cell, and pay more attention to the thin film cell application in the PV market. By the means of special fund and science and technology research program, the thin film cell producing technique shall be improved gradually, in order to make the product quality improved and more stable, in order to make the Chinese PV market develop and expand healthily.

3. Accelerate the industrialization of key equipments in large-scale grid-connected PV power[4][5]

In the grid-connected PV power system, inverter is the key equipment. The performance and the quality of the inverter determine the electricity quality, stabilization and credibility of the grid-connected PV power system. The efficiency of the inverter determines the power generation of the PV power system. At present, the R&D of large power and free-of-transformer inverter shall be sped up with the unit capacity of over 100kVA, and efficiency of more than 97%; the performance and quality of the large power series inverter shall be improved, and the industrialization shall be accelerated, so as to make the inverter play important role in Chinese large scale grid connected power.

Other relative key technologies for large-scale grad-connected power system also have as below:

● The automatic testing and control system in the large-scaled grid-connected power system can realize the unattended in grid-connected PV power and lower the maintenance cost of the power plant.

● Reliable solar tracking technology of the large-scale PV array can greatly increase power generation, and lower the power generation cost.

China shall speed up the technology R&D, by integrating the pilot application, continually improve the technology and promote industrialization, in order to provide the technical support for the large-scale grid-connected PV power plant.

6.2 Implement the large-scale and practical grid-connected PV pilot application

1. Grid-connected PV power is in line with the trend of PV application [2][5]

As long as PV power occupies a position in electrical power sector, the grid-connected power system is needed to be developed. PV power system percentage in the world is getting bigger and bigger. From the large-scale “Roof PV Plan” in USA, Germany, Japan, and other countries to the large-scale centralized grid-connected power plant, the accumulative grid-connected PV market had been over 80% by the end of 2007, becoming the main part of PV power in the world.

Through the 8^{th}, 9^{th}, and 10^{th} 5-year plan implementation, the grid-connected power technology has gained a lot of research achievement, the technological performance and parameters of the grid-connected PV system and the equipments can fully satisfy the requirement and regulation, the technology has been mature. However, the Chinese PV grid-connected technology is still in the stage of starting, generally, lags behind the international. Practical experiences on large-scale, marketization, and commercialization are absent. It is very necessary to carry out the practical pilot application of the grid connected PV power designedly and intentionally, with collaborating with the electrical power system closely, so that the technological

and economic issues and the electrical issue can be resolved. Especially with regard to the impact of large PV power grid-connecting on the grid, and the safety prevention of grid on the large grid-connected PV power, power dispatching, and operation and management issues all need to be studied in depths.

2. Large-scale open field PV pilot applications [2][5][6][7][8][10]

Large open field PV power plant is installed in the open field, such as desert, Gobi, un-cultivatable waste land, waste hill slope, and others, with the MW level power capacity. The power is mainly supplied to the main bone grid. Large open field PV power plant is most promising PV application, with the brightest future. By now, a lot of large scale desert power plants have been built and put into use world widely. In China, 10% of the land is un-cultivatable, such as deserts and beach land. Total area of deserts, semi-desert, potential deserted land occupy around 850,000 square kilometers; there are lots of barren mountains, hill slope, and the beach land in the mid-east of China. Based on the installation capacity as 50MWp per square kilometer, and by making use of the 30,000 square kilometers (about 3.5%) desert areas to install PV power system, the installation capacity can reach 1.5 TWp (equivalent installation capacity is 5TWp), which accounts for 62.5% of the total electrical power installation capacity. Large open field PV power plant will serve as the main energy in China in the future.

According to the "*RE Medium and Long Term Development Plan*" by NDRC, by 2010 the total PV power capacity will be 300MW, and large scale grid-connected power capacity will be 20MW. In Nov. 22, 2007, NDRC General Office released a notice to west eight provinces and required to present the pre-feasibility study report of building the large-scaled desert land grid-connected PV pilot power systems with the more than 5 MW. Also in the notice was specified that the feed-in tariff will be determined by tendering. The launching of these projects greatly promotes the Chinese PV market.

According to requirement of the "*State Medium & Long Term Science and Technology Development Plan Summary",* five MW-level grid-connected PV pilot plants projects in 11th 5-Year Hi-tech Program were deployed by national Ministry of Science and Technology (MOST), the emphases of the research are on 1) the effective forms of Chinese grid-connected PV power; 2) critical technologies; 3) the module equipment and the whole set. The project were planned to build four different PV power grid-connected plants and focus on the key equipments R&D. The implementation of the projects will largely bring the technical support for the planning, design, construction, equipment provision, and post-evaluation evaluation of PV power system and promote the grid-connected PV power pilot positively.

Whereas the severe hit of global financial crisis on the PV industry in 2008, it is

recommended that the implementation plan shall be modified, and increase the scale and accelerate the implementation, based on the "*Implementation Plan of Key Project of the MW Level Grid-connected PV Power System in 11th 5-year Hi-tech Program*" by MOST. The detail is shown in Tab 6-4.

Tab 6-4 Recommendations of implementation of large scale grid-connected PV power system

Project guide	"*Implementation plan of the key project of MW level grid-connected pv station system in 11th 5-year Hitech plan*" by PRC Ministry of Science and Technology (MOST) (The normal executive duration is 3-5 years)	Recommended solution (3-5 years)
Direction 1	MW level landscape and building integrated grid-connected PV power system and key equipment.	Build the landscape and building integrated PV power plant by selecting the appropriate places. Unit capacity 20kWp-1MWp. Overall installation capacity is 100MWp.
Direction 2	MW level BIPV pilot and relevant key equipments.	Build 3-5 BIPV pilot systems by selecting the appropriate places. Unit capacity: 20kWp-1MWp. Overall installation capacity is 100MWp.
Direction 3	MW level CPV grid-connected power and key equipments	Build 1-2 CPV grid-connected power plants in the solar energy abundant west provinces Each plant capacity of 50kWp-1MWp. Total capacity is 20MWp.
Direction 4	MW level and high voltage grid-connected PV power pilot and key equipments.	Build MW level open field high voltage grid-connected power stations in Western China; with a minimum single station capacity of 1MWp. Overall installation capacity is 1,000MWp. The plant site should be plenty of solar energy, and conditions of power transportation and the land resource, etc are favorable.
Direction 5	Performance testing and eco-technical analysis on large scale grid-connected PV power plants	From the above research direction No.1-No.4 in this table, select 1-2 power plant, make the perform testing, economical analysis, building structure and management mode.

3. Study on the technical and economic issues of large-scale open field grid-connected PV power [19][20][21]

In practice, there are still a series of technical and economic issues to be solved in the grid-connected operation of the open field large-scale PV power station. On the aspects of safety, reliability, operation management, power dispatching, and so on, lot of questions needs to be investigated in depth. In the pilot application and test operation, the initiative of the Power Companies and Grid Corp shall be exerted, so as to gain the practical experiences of the large-scale grid-connected PV generation,

and lay a good foundation for large-scale PV power applications, by operating the project commercially and adopting the tariff subsidy system.

At present, the research emphasis' are as follow,

(1) Research on the site selection of the large-scale PV power plant in open fields

Besides solar energy resource, the situation of grid-connecting shall be surveyed deeply, including electric transmission line, load capacity, voltage level, and main power sources etc. Inner Mongolia can be selected in priority as the demonstration region in study.

(2) Research on the adaptability of the power grid load on the large-scale grid-connected PV and reliability of PV power

According to the comprehensive load curve of the grid, and seasonal change of the characteristics curve of PV power at different sites, the relation between conventional power capacity of the electrical power system and PV power capacities can be determined by comprehensively analysis.

(3) Research on power transmission and energy storage of super large-scale PV power

AC transmission for high voltage or extra-high voltage, DC transmission for extra-high voltage, pumped storage, chemical storage, hybridized with hydro-power, wind power and other power sources, the application and research of smart grid.

(4) Research on the influence of large-scale grid-connected PV applications on grid

Research on the influence of large-scale grid-connected PV applications on electrical power systems, such as the effects on rotating inertia, the stabilization of the system, dispatching capability, etc, and voltage flicker of the electrical power equipments, harmonics, and negative sequence, and other unbalance issues on the electricity quality of electrical power system.

(5) Establish the research and testing base of a large-scale grid-connected PV power

Conduct research on super large-scaled PV power plant, with regard to operation & maintenance, power dispatching, controlling and protection.

Develop the computer programs, appropriative equipments and devices.

4. Large-scale urban distributed grid-connected PV pilot applications[2][5][6][7][9]

Urban grid-connected PV power systems includes the BAPV system (PV panel can be install on the roof of building) and the building integrated PV systems (BIPV). PV roofs can not only save the land area of photovoltaic arrays, but also the overall

electricity transmission cost and the loss of electricity can be deceased, for that the power system is adjacent to the load.

BIPV and BAPV system can be adopted in the new buildings, which save the construction material. PV panel can be installed on the roof of existing buildings, with simple structure and simple maintenance, in which the basic structure does not need to be retrofitted, and the solar energy can be utilized fully. It is the effective form of the urban practical grid-connected PV power system. China had above 40 billion square meters construction areas, with roof area over four billion square meters, plus the southwardly walls, the utilizable areas excess five billion m^2. If 20% of the five billion m^2 area is installed with PV panel, the installation power capacity is roughly 100GW.

Most of the grid-connected PV power in the world are the roof grid-connected PV system; for example, the “Million PV roof plan” in US (1997), “1,000 roof plan” (1990)” and “100,000 PV roof plan” (1999) in Germany, “Sunny Plan” and “70,000 roof plan” (1997) in Japan. In China, PV grid-connected system is still in the stage pilot application, only about more than 100 PV grid-connected power systems with variety of capacity. According to the “*Medium and Long Term Development Plan”* by NDRC, PV power system shall be installed on the urban buildings and public facilities; the grid-connected PV power system shall be installed in the public building roof in large and medium size cities, and spread to other buildings. By 2010, 1,000 PV roof power project will be built with an installation capacity of 50 MWp. By 2020, 20,000 PV roof power projects will be built, with an installation capacity of 1 GWp, obviously, the target does not accommodate with the current situation. For example, Shanghai initiated 100,000 PV roof program in 2006, and planned to build roof PV system with installation capacity of 400MWp during 11^{th} 5-year plan. Jiangsu province planned to implement the “PV roof project” in airports and large & medium size cities, with the installation capacity of 550MWp by 2010.

It is suggested to adjust the target of plan, expand the implementation scale and scope, and accelerate the process. Besides installing the state-owned or the group –owned PV power systems, a certain scale end user owned grid-connected PV system shall be built, so as to probe the financial models of utilizing the idle social capital, and to acquire the experiences of O&M, safety of grid, and electrical power dispatching with regard to the small capacity, large scale, distributed grid-connected PV power system. The spreading of PV power grid connected systems pilot shall be started in large and medium size cities firstly within 2-3 years; it shall spend 5-10 years to generalize the PV power system in large scale. If one percent of the roof and southward wall areas of five billion sq meters are used to install solar cells, the installation capacity will reach 5GW. The installation t

Tab 6-5 Suggestions on urban grid-connected roof system

PV roof type	Installation unit quantity	Average unit capacity (kWp)	Total installation capacity(MWp)
Large scale commonweal buildings	2000	50	100
Universities or schools	50000	10	500
Governmental buildings	50000	10	500
Factory workshop roof	5000	20	100
Hotels or other entertainment location buildings roof	5000	10	50
Household PV roof power system	500,000	2	1000
Total			2250

6.3 Establish sustainable mechanism to strengthening the capability building and talents education

1. PV power expertise building of capability

It is prerequisite to accelerate the capability building of the PV power in order to fit with the rapid development of PV industry and meet the demand of Chinese large scale PV power market. PV power associated capability building include: resources survey and evaluation, basic technology and product R&D, quality supervision system and service system, CDM and management training system of various level and type personnel. According to "*RE Development 11th Five Years Plan*", the following actions shall be taken as early as possible.

1) Establish expert team or specific organizations to complete the resource general and detailed investigation cross the country and the important region, including the solar energy resource, available and economic desert areas, roof area, electrical power transmission facilities, and the load situation in the relevant areas. The national level or provincial level databases shall be established, providing basic data and information.

2) Enhance the capability of quality supervision systems and technological level, improve and strengthen the function and authoritativeness of the supervision organizations. Establish credible quality accreditation system and PV industry supervision system, so as to maintain the healthy growth of the market.

3) Link to the international system; establish corresponding CDM consultant services and governmental application channel. The commitment of reducing emission shall also be profitable. Enlarging the international influence and showing the Chinese responsibility as a powerful country, also ensuring the preserved profits.

2. Setting PV power major and educating professional talents

4) Talent is the foundation of the development of the industry. On other than improving the professional quality of the practitioners, the rapid and sustainable development of PV industry shall be able to assured. Establishing the long term professional training system, educating the talents with different level and different specialty, in order to provide the plenty and credible human resources for the PV market and industry development. The stress shall be laid on the talents education of the fundamental theory and the practical technologies. The training of the research and development of the PV power practical technology shall be intensified.

5) Setting the PV power major in the top ten higher educational institutions, and setting five Master Degree conferring points and at least two PV power Doctor's Degree conferring subject point, in order to educate the PV power senior professional talents, Fostering 50-100 students with bachelor degree, 5-10 graduate students with Master Degree, and 1-2 with Doctor Degree annually, so as to meet the strategically development needs.

6) Setting PV power major in 10 colleges and technical secondary schools, for the purpose of training the practical PV power technology and PV product R&D talents.

3. Establish the long term and sustainable training system

1) Establish PV training system with professional training facilities as soon as possible, and set up the special training institutions for the different level and knowledge. Mainly focus on the knowledge training and the improvement of professional skill. Improve the professional quality of the employees and accelerate the recognition degree of the people on PV power.

2) Establish two or three national training institutions of "Renewable Energy Power", in order to train the trainers and lectures for the local training facilities, organize multiple types of high-level training, lectures, international/domestic academic & cultural exchanges and seminars, etc.

3) Establish 5-10 provincial renewable energy power training facilities to train technical personnel of PV power and other RE power, and maintenance and management personnel, and hold the senior training, lectures, academic exchanges and seminars.

4) Department of Human Resource and Labor Security shall list the PV power system maintenance and management worker as an occupational title. Hold the occupational training course in around 30 secondary technical schools, in order to lift up the professional quality of PV power system maintenance and management staff.

5) Establish the training institutions and the qualification accreditation system of the practitioner. Only the staff holding the certificate can engage in the work.

6) Make standard, regularize the teacher, textbooks, training facilities, training requirements and accreditation in the professional training institutions.

7) By taking all kinds of measurements, strengthen knowledge dissemination of PV power and popularization of the scientific knowledge, and improve public sense. Make officers, finance institution staffs, students from preliminary and middle schools, and the public have the sense of environment protection and clean energy utilization, be acquainted with the strategic position of PV power, and the basic principles and features of PV power. The public shall learn and understand the policies for renewable energy and PV power and to support PV power.

6.4 Strengthen quality control and inspection mechanism, improve quality of products

Reliable quality guarantee mechanism should include three parts as follows: 1) release series standards of product quality, 2) perform the strict system of quality guarantee, inspection, and accreditation, regulation and codes for products quality, 3) establish the authoritative and effective assessment, supervision, and management mechanism.

1. Improve and strengthen the technical standard of PV system

Whereas the current PV standards in China are the recommended, lacks of compulsoriness and authoritativeness, which have impact the executive of the technical standard and Chinese PV market development. The national standard responsible administration shall turn the “recommend to perform” into “must carry out” with the national standards which have the important effect on the PV power system.

In terms of the standards adopted from IEC standard and linked to the international must be transferred into the compulsory standards; at the same time, the pace of standard making should be accelerated. Experts shall be organized to make the criterion on PV power system, especially on the standards for grid-connected PV system and technical codes.

PV standards to be publicized should be released in other way and make the PV industry follow, in order to ensure smooth development of PV market.

2. Implementing compulsory product accreditation system and link to the international

Compulsory product accreditation is the international general practice and the authority accreditation mechanism is the basis of quality guaranty. Strengthen the status of national “China Photovoltaic Test Center” according to the international requirement and the deployment. The domestic existing PV test center should be retrofitted in the equipment updating and technology upgrading, enhancing the test

capability and level. Cooperate with the foreign famous PV test institutions, and carry out the test result comparison, enhance the domestic PV test institution capability and the position, and make the international recognize the result of Chinese testing center of PV.

Establish the grading system of test institution according to the capability of equipment and technology condition. Levelize the standards for product performance test and assessment, implement compulsory market entry systems for PV products test, and affirm the effect and authority of the test result.

Implement strict accreditation system of the quality control for PV products, accelerate building the Chinese PV products accreditation system and assure the scientificness, adaptation, and maneuverability of accreditation system. Make the document and procedure of accreditation, entrust the institutions, which were awarded the accreditation qualification, to carry out the product inspection, and confer “China PV Product Golden Solar (CGS) “certificate to related institution according to the national and international standards.

3. Strengthen mechanism of the inspection assessment and supervision

Inspection, assessment, and supervision mechanism include making of quality standards, regulations and agency establishments.

1) Firstly, guidance on power supply services shall be clarified. The terminal product of PV power system is the power supply service meeting the quality requirements of consumer for both off-grid and grid connection PV power system. Inspection and supervision are the indispensable links for full quality control chain of PV power system, not only being responsible for the PV power system constructing, but also supervising and assuring the sustainable operation.

2) Organize PV power and electric power sector experts to specify the mode of the system construction, operation, procedure, and management criteria. Stipulate the link of quality control for assessment, supervision, and acceptance; make the standards of quality assessment, and the content and manners of corresponding inspection and acceptance.

3) Establish national “PV Power Quality Management Office” which is fully responsible for the quality control and supervision of PV power system construction and operation. Establish or select the neutral certificated institution as “China PV power technology consulting company” to provide advice and consultant for the construction and operation supervision, and make the quality assessment, inspecting and accepting.

4) During project implementation, project ownership shall be fixed firstly and the system of the project ownership responsibility shall be conducted. Project

ownership is responsible for the project construction tendering, management regulation, and maintenance and operation, and the operation of power supply.

6.5 Relevant regulation and incentive policy making and improving

As "*China Renewable Energy Promotion Law*" came into practice, a series supportive policies and regulations for renewable energy development have been released by State, which provides the law basis and policy security for Chinese renewable energy power large scale development, and greatly drive the development of renewable energy power market. In recent years, investment in wind power is the hot spot and the large scale wind farms have been established one by one, the market is explosively developing, which shows tremendous drive of the law and complete supportative policies upon Chinese renewable energy power market development.

However, the effect of the current renewable development supportive policies on PV market is not evident, mainly being attribute to the policy of "one thing, one discuss" in the regulations in terms of the PV power project. It is very necessary to turn the policy of "one thing, one discuss" into market operation model of "pricing via bidding" similarized to that of the wind power bidding, which greatly promotes the development of PV power. It is urgent to enact and improve PV related supportive policies and regulations, to provide necessary assistance for PV power developing, according to the current PV power characteristics.

1) "*China PV industry reconstructing and developing summary*"

According to the present situation that Chinese PV industry mainly depends on foreign market, enact "*Chinese PV industry reconstructing and developing summary*" as soon as possible, so as to tackle the financial crisis effectively, and release the emergent polices and measures of Chinese PV industry, such as increasing the ratio of export tax rebate. Launch domestic PV market in large scale as soon as possible and increase the subsidy strength, increase the internal demand of PV market so as to compensate the shrinkage of the international PV market.

2) "Guideline on PV grid connected power project implementation"

Relying on law and regulation to guarantee the development of PV market, especially the compulsory regulations and requirements, which adapts to Chinese situation, shall be specified, for example, certain percentage of PV power generation must be specified as well, reasonable profit of electric power Corps shall be assured, motivate the initiative and responsibility of grid Corp to participate in PV power application.

3) "PV *power deed-in tariff*"

According to existing regulation and policy on renewable energy tariff, properly

increase the tariff add-in income, and definite the supporting degree on PV power. Enact the "*PV power deed-in tariff*" in accordance with the current PV power economic and technical situation, and specify the PV power status in renewable energies and its definite share in the "*RE power Tariff Add-in Income and Allocation*"; implement the policies of PV power subsidy to assist the PV market's development.

4) "*Guideline of PV Power Project Construction and Operation"*

Regularize the regulation and requirements for PV power projects proposing, construction, operation, and the management, especially the preferential policies and the treatment on project construction and operation, such as loan interest derating, tax derating, and long term favorable loan. With the national R&D and demo technology-contained project, the state shall grant certain percentage of public fund, as the part of initial investment, without sharing the dividend, sharing the risks, so as to promote the commercialization of the large scale PV grid-connected power.

5) "*Criteria of PV power market conduct"*

Implement market entry mechanism of the PV enterprisers and products, avoid disordered competition. Rigorously enforce the product accreditation system and regularize PV market to guarantee PV projects quality and ensure a healthy and orderly development for PV power market.

6) *"Management regulation of PV power system operation"*

Definitude the guiding thoughts of power supply service, enact the unified and standardized code of PV power system operation and management. Define the relation, responsibilities, rights and obligations among PV power generation, suppliers and consumers, along with the requirements of PV power enterprisers and practitioners.

7) "*Code of supervision management for the construction and operation of PV power project*"

Strengthen the supervision management for construction and operation of PV power project; clarify the requirements and codes of supervision and inspection, and the punishing measures of deregulation. Establish the functional institution, conduct the inspection and the supervision, in order to assure the PV power project construction quality and the full operation benefit exertion.

8) "*Management measures of rural off-grid PV power system construction and operation*"

Whereas the important role of off-grid PV power system in Chinese rural electrical construction and the future PV market in China, organize the expert team, constitute the measures based on the off-grid PV power system construction and

operation in Chinese rural electrical power construction and the practical experience of “SDDX”. Regulate the construction and operation of village PV power plants and solar home system, based on the renewable energy laws, related regulations, and standard requirements.

The key issue of rural off-grid PV projects is the ownership. In order to carry out power supply service and tariff collection, based on the principle of “same quality same tariff”, local power utility is proper to take the responsibility of the ownership, fully responsible for the project construction along with the operation maintenance. Define the power supply formula and perform the technological design, on the basis of the principle of adapting to local conditions and the best combination of different energy resources to optimize the power supply manners and technological scheme design, by following the national standard of 200 kWh as per capita annual electricity consumption to reach the power supply target. The cost of project construction is shared by three parties of central, local government, and consumers. Tariff subsidy shall be put into effect under the rules of renewable laws and related regulations. By integrating to solve the left issues from existent project implementation, make viable rules for implementation and smoothly carry out new projects.

9) “*Implement rules of large scale PV power plants construction in open field”.*

The MWp and above level PV power plants in the open field, with the purpose of electrical power generation and transmission, should be sponsored by the electrical power Corp, who conduct the construction and management, so as to guarantee the electricity safety.

Local DRC takes charge of large scale PV power project implementation. NDRC and NEA control the total capacity of PV installation based on national energy development plan and finance condition, and release the guiding document of implementation scale upper limit and highest feed-in tariff. Provincial DRC proposes project, and submits to NEA for the approval.

Large scale PV power plants in open fields adopt the model of “wind power”, by concession bidding and balance tariff subsidy used in wind power. Encourage and support all kinds of non-state owned capital investment and local government supplies favorable conditions for financing, loan, land, and tax. The reasonable profit of the investors shall be considered as determining the feed-in tariff.

10) “*Implement measures of urban PV grid connecting”*

Urban PV power system includes two types, one is the PV system installed on the roof of buildings, another is the building integrated PV (including PV curtain). Those two type PV power systems are connected to grid in low voltage to satisfy the own use. Urban PV power system shall apply for the approval from local power

utilities and report to local DRC for record and summing up. The investment cost of the project shall be raised by owners and users selves. The state provides one time capital subsidy shared by central and local government at a proportion. In principle, the PV power tariff does not enjoy the balance tariff subsidy.

For urban PV power system with bigger capacity, besides the own use of PV power, redundant power needs to supply to the grid, if the project owner asks for tariff subsidies, project owner shall declare before applying for the project. By the means of the PV power system construction, subsidy format and the quantity of subsidy shall be fixed after hearing the public scrutiny before the approval.

NDRC is responsible for macroscopic adjustment and control of urban PV grid –connecting, release the guiding document on the regulation of urban PV project implementation scale and subsidy of different PV power system in time, jointly with SERC implement the supervision.

11) "*Implementation measures of urban and rural distributed home grid-connecting PV power"*

For the less than 10 kWp, household owned PV grid-connected power system in urban and rural areas; it shall be supported as the condition is approved. For urban household owned PV grid -connected power system, follow the above mentioned "*Implement Measures of Urban PV Grid-Connected System*", low voltage grid-connection, power self generate and self consume, self-financing and government subsidy. User applies for the project; local electrical power company examines the feasibility and gives an overall consideration. Local electrical power company is responsible for supervision and use guide of PV power system.

PV poverty alleviation could be demonstrated in rural areas, where grid reached. Few poor households can build the home PV grid-connected system and gain income from tariff subsidy accordingly. For PV poverty alleviation project, project capital shall be from the consumers, government, low interest loan, tax derating, free service of consultant and technology by the government. With the PV poverty alleviation project, user presents the application for the project; local electrical power company examines the feasibility and arranges as whole. Local electrical power company is responsible for supervision.

12) "*Implementation Rules on Urban Emergence PV Power Supply Source Project Construction and Operation*"

Understand the importance of PV emergence power source in depth, at first install the PV emergence power source in urban emergency shelter. The purpose of PV emergence power source is to supply emergent power as the grid is power off during emergency affairs, PV emergence power supply can be equipped with battery,

and be hybridded with other energy, in normal time, power is generated and supplied to grid, in emergent case, the system can supply power standalone.

The construction funds of PV emergency power source are mainly from the local government and partially from the central government. Under precondition of emergency power supply, commercialization operation mode is optional to introduce other capitals and benefit from grid connection in the normal time is taken as the return of the initial investment.

Local government and DRC take the overall responsibility of PV emergence power supply project implementation; and instruct local electrical power bureau to take the owners' responsibility, in charge of project construction and operation. The priority for PV emergency power source is to guarantee the project quality and perfectly able to supply power in emergent cases. The details are listed in appendix No. 10.4 -"*Guideline on the Emergence PV Power Supply Source Project for Emergent Public Affairs Response and Tackling System* (proposed draft)".

6.6 summary

In this chapter, the proposals on the measures and policies of accelerating domestic PV market and promoting industry development are presented, including:

1. With regard to the proposals on industry development, refer to the international poly-crystalline silicon development model of "mainly expansion and with less new building", the state increase investment of enterprises with technology and industry base, accelerate R&D and industrialization of independent intellectual property and narrow the difference with the foreign poly-crystalline silicon producer, and insure a harmonic, healthy, stable, and everlasting development of poly-crystalline silicon industry development.
2. The state increases the investment on the research, so as to master and improve the key technology and lower down the investment cost of PV power, increase the support strength of capital and human resource to further improve and upgrade the key technology of Chinese silicon purification technology and impel PV module price return to the normal level.
3. Pay much more attention and support to the thin-film solar cell to make solar cell production technology improved and matured, and enter the stage of large scale application. Accelerate the technical research of key equipments of the large capacity and high efficient grid-connected inverter and speed up the industrialization to provide the technical support for large scale grid-connected PV power plant construction.
4. Implement the large scale PV grid connection practical pilot application with clear targets and intentionally, collaborate with the electrical power departments

and enterprises to solve the relevant technical and electrical power management issues. Accelerate the implementation of “Renewable Energy Medium and Long Term Plan” , increase large scale PV grid connection power system and PV roof power system application scope and the scale, speed up the schedule, probe into the investment model of private capital, and gain the experiences on system operation, grid safety and electricity dispatching.

5. Enhance the capability building on resource investigation and assessment, basic technology and product research, quality supervision & service system. Establish training and education system for each level and type of staffs. Set up PV power major in colleges and national and local “Renewable Energy Power Training Center” to educate talents with various levels of PV power. Enhance the training and public science dissemination of PV power basic knowledge and improve the senses of environment protection and clean energy utilization.

6. Establish the quality guarantee system to improve the product quality, such as, release and implement the compulsory product quality standard, set up national test institution, establish the quality accreditation system linked with the international institutions and having international impact, and establish the authoritative, complete, and effective systems of inspecting, evaluating, and supervision.

7. Insist on scientific development and human-oriented concept to actively introduce the first class PV technology talents. First class talents are the important resource which plays the key role in the PV industry development. With the talents, China will keep the important scientific and technical development position, hold the PV scientific frontier and developing direction of PV industry, gain creative results, and improve PV industry’s competitiveness. The relevant departments shall make effort to create favorable conditions to strengthen the international cooperation, to actively introduce the international talents in PV industry. At present, make effort to introduce the talents of Si material purification, wafer slicing, and photo-electro conversion technology, and so on.

8. Promote the green electricity tariff reform. PV power tariff is the most sensitive link of PV industry chain. It is suggested that based on the principle of no influence on residents living and promoting the whole society energy saving and supporting the renewable energy development, properly level up the conventional electrical power tariff, to support green electricity development including PV electricity.

9. Proposals on PV power project implementation principle:

   [1] NEA plays roles of macro-control with the total capacity and subsidy scale

of the province presenting PV power projects.

[2] Constitute and improve the PV power supporting policies and regulations. By referring to wind power bidding mode, turn the PV power policy of “one thing, one discuss” into the marketization operation mode, in order to promote PV grid connected power system construction greatly.

[3] NEA verifies and approves the PV power projects presented by provinces, via bidding like the concession project of wind power.

[4] Through the flexible, multiple channels financing mechanism follow the principle of “reasonable cost plus reasonable benefit”.

[5] Private capital investment on PV power projects is favorable.

References

[1] Ma Shenghong, *Investigation Report of Jiangsu PV industry status*, Nov, 2008

[2] Zhao Yuwen, Wang Sicheng, et al. *China PV Industry Development Report (2006-2007),* NDRC/GEF/WB/ REDP PMO, PV Commission of China Renewable Energy Society, May, 2008.

[3] *MOST Website. Project application guide: Application guide for Thin-Film Solar Cell Complete Key Technology Project, Hi-tech Research Program, Advanced Energy Technology*, Aug 18, 2008.
www.most.gov.cn/tztg/200808/P020080818616178432976.doc

[4] MOST Website, *Application Guide for 2008 Special Task of 863 Program*, Advanced Energy Technology Field.

[5] http://www.most.gov.cn/tztg/200805/P020080522405385309328.doc, 2008-05-21

[6] MOST, *Application guide for “MW PV grid-connected Power Plant System” of National 863 Program, Energy Tech*, Oct 1, 2006. www.most.gov.cn

[7] NDRC, *Renewable Energy Medium and Long Term Development Plan*, Sep, 2007

[8] NDRC, *Renewable Energy 11th 5-Year Development Plan*, Mar 19, 2008.

[9] Li Junfeng, Wang Sicheng, et al, *China PV Development Report 2007*. China Environment Science Press, Sep, 2007.

[10] Yu Bo, Domestic First Solar PV Curtain Wall Five Star Hotel-Baoding “Electricity Valley *Jinjiang” Leading China,*, Civil Works Technology, 2008(06), p52-53.

[11] Ma Shenghong, Kong Li, Chen Dongbing, *Pre-feasibility Study on Dunhuang 8MWp PV grid-connected Power Plant*, Solar Energy, issue 6, 2004, P5-9.

[12] Institute of Electrical Engineering, Chinese Academy of Sciences, *Proposed Report on Chinese 11th 5-year PV Development (research report)*, May, 2005.

[13] IEE, CAS, *Proposals on Establishing Training Mechanism of Renewable Energy Power Supply in China Rural Area (research report)*.

[14] Ma Shenghong, Chen, Dongbing, *Study on Quality Control Chain of Off-grid Village Power System (research report)*, Renewable Energy Power Consulting and training Center, Chinese Academy of Sciences, Sep, 2007

[15] Wang Sicheng, *Study on related issue of Chinese PV Power*, China Energy, 29(2), 2007 p7-11.

[16] NDRC, *Trial Measures for RE Power Pricing and the Expense Allocating*, Jan, 2006.

[17] www.ndrc.gov.cn/zcfb/zcfbtz/tz2006/W020060206506597675623.doc

[18] Yan Luggage, Chen Junwu, *Study on several key issue of China energy sustainable development*, Science Press, March, 2007.

[19] Hu Xuehao, Zhou Xiaoxin, *Outlook of super large scale PV Power Development in China*, Issue 11, 2004 (total No. 197).

[20] Zhou Xiaoxin, Hu Xuehao, Pre-feasibility study on super large scale PV power *and electrical system in China*.

[21] *Report of China Academy of Electrical Power*, Apr, 2004

7. Analysis and Proposals on the Implementation of "China PV Upspringing Plan 2009-2012"

7.1 Government takes urgent actions to help PV enterprises out of dilemma

1. The serious hit of the financial crisis on Chinese PV industry

For the new international PV industry situation, together with the sudden international financial crisis, the Chinese PV industry is facing the austere situation.

The latest international research and analysis of PV (Deusche Bank, HSBC, EPIA & Green Peace, PV News, Solar News Letter, etc.) show that since 2009 on, the solar grade poly-crystalline silicon will be in the situation of supply over demand, and will last 2-3 years. At the same time, the world's solar cells, PV module production capacity will also increase, the supply-over-demand will cause prices to drop significantly.

The financial crisis made Germany and Spain tune the PV tariff subsidy policies, which has seriously affected the world PV module sales. It is estimated that German market in 2009 will not have positive growth, and Spanish market will drop from 2660MWp in 2008 to 500MWp in 2009. Since the sum of German and Spanish PV market occupied 68% and 72% of the global PV market in 2007 and 2008 respectively, so the decline of German and Spanish PV market will have a significant impact on the world PV market. Although the United States and Japan have unveiled new subsidies and preferential tax policies to be put into force in 2009, the two countries together only shares 24% and 12.5% (solar plaza, 2009/1/23) of the global PV market in 2007 and 2008 respectively, and the growth of American and Japanese PV market is far from enough to compensate the fall of market in Germany and Spain. This is undoubtedly a tremendous hit on Chinese growing PV industry, as 98% of whose products are exported to Germany and Spain. Decrease in production and decline in exports have already come into being.

Also, the global financial crisis has led to the sharp falling of petroleum prices, globally alleviating the international demand on energy, which brings additional negative impact on the high cost PV power. As the global demand drops, many orders were postponed or canceled. Since Oct, 2008, most of Chinese PV companies have experienced the losses. Some small and medium-sized companies have ceased their production, facing the risk of being merged or going bankruptcy.

2. Chinese PV industry facing challenges

China has become one of the world's biggest PV countries, accounting 27.2% of the world's total production in 2007, ranking the first in the world; accounting for 31% of the world's total production in 2008, continuing to be the top of the list. However, Chinese PV industry as a whole is weak, especially with the "PV market's unduly reliance on the foreign" problem, which makes the entire Chinese PV industry under huge risk. Once Chinese PV industries were severely hit, in short terms, the direct impact may be the hundreds of billions of loss in production and export. In the long term, it could lead to serious setback for the PV industry, and also a disaster to the Chinese PV industry.

Although the sharp shrinkage of market demand for PV has been brought about with the global financial crisis, the PV companies are striving for new development and breakthroughs. Considering that PV energy and other new forms of energy could bring new economic growth, the nations around the world will continually support the major policies on PV as the general direction. The United States Congress passed the bill of the renewable energy tax extension; Japan will resume the PV subsidy policy for installation of PV power system. With overcoming the financial crisis, PV and the new energy will be the new business and profit growth points for banks and other financial and investing institutions. Therefore, in terms of the global financial crisis, even if the PV market was undergoing relatively large effect, in the long term, the activation of favorable policies on PV will work along, with the market growth of PV industry.

Going through the financial crisis, Chinese and the world's PV industry will both experience a renewal. The world's PV industry will step into a new period of time with healthy and benign development, with the decreased cost and increased efficiency due to the industrial chain integration and innovation internally, prices of PV product return to a reasonable level. The Chinese government should take the chance to accelerate the development of domestic PV market, not only bring Chinese PV power to a new level, but also help Chinese PV industry to avoid the regression, bankruptcy, and reduce the loss.

3. *China PV Upspringing Plan 2009*" (PVUP 2009)

In order to help the Chinese PV industry to overcome the difficulties, it is recommended that the state takes urgent actions, by launching the important plan concerning the expanding of PV application- "*Chinese Photovoltaic Upspringing Plan in 2009-2012*", shortened as "*China PV Upspringing Plan*

2009" (PVUP 2009).

1) The technical conditions of starting-up of large-scale PV market are all ready

(1) Chinese PV industry is getting integrated and matured

With the few years rapid growth, the Chinese PV industry have developed a number of world-class leading enterprises, and have become the first large solar cell and PV module producing and exporting country in 2007 and 2008 in the world. With the growth of industry, scale, Chinese PV industry has owned the leading technologies of the research and manufacturing of cell and the significant advantages of lower cost. The industrial chain and the industrial clusters are gradually being improved. Especially, the important and core breakthroughs have been attained continually in key technologies, equipments, and the techniques on the fields of poly-crystalline silicon material fabrication. Balance is gradually achieved between the upstream and downstream of the industrial chain, and the industry chain is becoming more and more complete. The passive situation that high-purity silicon material unduly relies on import, and was always controlled by the foreign has been changed.

(2) Off-grid PV power technology is mature

The implementation of "SDDX Program", "World Bank REDP", "Sino-German KFW Financial Cooperation Program" and other large-scale off-grid PV power projects haw driven greatly the production of solar cell manufacturing, has promoted the R & D and production of inverters, controllers and other components of PV power system, has also trained and produced a large number of technical talents on the design of PV power applications, installation commissioning, operation and maintenance. Furthermore, the valuable experience in marketing, management, quality control, and after-sales services have been learned from the above projects implementation. With few years of efforts, the practical use of Chinese off-grid PV power, in terms of scale and technical level, have been at the international forefront, the strengths of the human force, technology, equipment for the construction of off-grid PV power system are all ready.

(3) Grid-connected PV power conforms to the current international trends

Grid-connected PV power is the direction of development of PV power, and is the mainstream of the world's PV power. The Chinese government has paid great attention on the technology of grid-connected PV power. Through research on grid-connected PV power technology, China has achieved initial

accomplishment on grid-connected PV power system, technologies on the controllers and inverters of large-scale PV power plant. Grid-connected inverters of more than per unit 150 kWp has also been developed by enterprises, and has been put into use with good performance and results. During the period of national 11th 5-year plan, the research of the technology of grid-connected PV power was also listed as an important research project, and the research on grid-connected PV power system design, key equipment R&D, and BIPV have been stressed, and the research on the grid-connected PV power technology has been sped up, a several grid-connected PV power pilot plants have been built. The construction of the grid-connected PV power pilot plants promoted the technologies of grid-connected PV power very much. At present, Chinese grid-connected PV system fully meet the international standards in fields of critical technology, product quality and power quality, etc, in line with the requirements of Chinese electric power system. 80% of the inverters produced by some domestic companies are exported to Europe and America. The technical condition for China to carry out large-scale grid-connected PV power is in place.

2) Regulations and policies on large-scale PV power are in place basically

(1) "*Chinese Renewable Energy Promotion Law*" enacted and put into force

"*Chinese Renewable Energy Promotion Law*" came into effect on Jan 1, 2006. "*Renewable Energy Promotion Law*" clearly states that the initial investment for renewable energy power project shall be covered by the project developers. The Grid Corp shall fully purchase the electricity supplied to the grid at a reasonable tariff (cost plus a reasonable profit). The additional part beyond the conventional feed-in tariff shall be apportioned by the Utility Grid by means of collecting the tariff add-in from the users. "*Renewable Energy Promotion Law*" is the law basis of Chinese large-scale and commercialized PV power development. It also serves as the law reference for the supportive financial supporting and other preferential policies by government in the initial stage. What is needed currently is to make out the relevant supporting policies and regulations for PV power, and conduct the macro-control and guidance.

(2) The supporting policies for "Chinese Renewable Energy Promotion Law" has been in place

In order to ensure the implementation of "*Chinese Renewable Energy Promotion Law*", NDRC and other administrations have issued the supporting policies for the law, such as "*The Supervision Measures for that Grid Corp fully*

Purchase of the Renewable Energy Electricity"（being put into force since Sep 1, 2007）, "*The Trial Measures of Renewable Energy Power Tariff Add-in Collection and the Allocation*" (NDRC, Pricing [2007]Nao.44）, and so on. In the above policies and regulations, it is emphasized that the Grid Corp must purchase renewable energy electricity in priority according to the "*Chinese Renewable Energy Promotion Law*", and in priority dispatches the renewable energy power, sort the generating units of non-adjustable wind power, solar power, and other renewable energy power as the first. The renewable energy tariff add-in collection and the practical operation procedure of tariff subsidization were also specified. It is obvious that the political and law conditions for the Chinese PV power scalization and marketization has been set.

(3) It is the time to implement large-scaled PV power projects

- Domestically, the inventive policies for PV power have been in place on the national level, each level of government have paid great attention to PV power. From the experience from the rapid development of wind power in China these years, it can be shown that the large scale PV power can be operated commercially and developed very quickly, by implementing the specific policies and maneuverable rules, and by making out the rules similar to the "pricing via bidding" of wind power farms project in China.
- As the energy and environmental issues become more and more serious, large scale developing of the renewable energy power came into a consensus in the society. The public and the society have a very highly recognition on PV power. The government and the public can understand the cost and profit of PV power objectively, comprehensively and scientifically. Launching the large-scaled PV power projects will gain the widely support and recognition from the public.
- The rapid development of PV industry and technology has lowered the PV power cost to a great extend. The pressure of the global financial crisis make PV power cost back to a reasonable level. The best example herein is that the average bidding price for Dun Huang 10 MWp grid-connected PV power project was around RMB 1.3-1.4 Yuan/kWh, and the lowest bidding price is only RMB 0.69 Yuan/kWh.
- Under the favorable conditions, starting-up the PV power project in large scale and in time not only help the Chinese PV industry to overcome the financial crisis, but also save the large amount of governmental

investment, enlarge the project scale, reach the target in "*RE Development 11th 5-year Plan*" and "RE Medium and Long Term Development Plan" ahead of time, which is beneficial of the nation and people, with promoting PV power to exert its role and position in the electrical power energy structure.

4. Launch and implement Chinese large scale PV application project-"PV Upspringing Plan 2009"

1) Chinese PV power development targets planned

In the "*Chinese RE Development 11th 5-year Plan*" and "*RE Medium and Long Term Development Plan*" by NDRC, it was specified with development targets in PV power. The target in "*RE Development 11th 5-year Plan*" is to reach 300MWp installation capacity in 2010; in "*RE Medium and Long Term Development Plan*" the target is to reach 1800MWp installation capacity in 2020. NEA issued in Feb 2009 "*Energy Prosperity Plan (2009-2011) (draft)*" in which the targets are to newly install as 500MWp, by 2011 the total installation capacity reach 640MWp. It is evident that the targets value in "*Energy Prosperity Plan (2009-2011) (draft*)" were increased a lot, than that in "*RE Medium and Long Term Development Plan*". In Tab 7-1 is listed with China PV power targets by type in RE development plan.

Tab 7-1 China PV power targets by type in RE development plan (MWp)

Market type	By 2010 (11th 5-year plan)	By 2020 (Medium & long term plan)	(2009～2011) Energy prosperity plan
Non-electrified area electrical power construction	100	300	Additional capacity 500 MW Investment of RMB 30 billion
Urban PV roof and lighting	50	1000	
Open field grid-connected PV power plant	50	200	
Accumulative total	300	1800	640
*Annual average increment after 2009	80	138	167

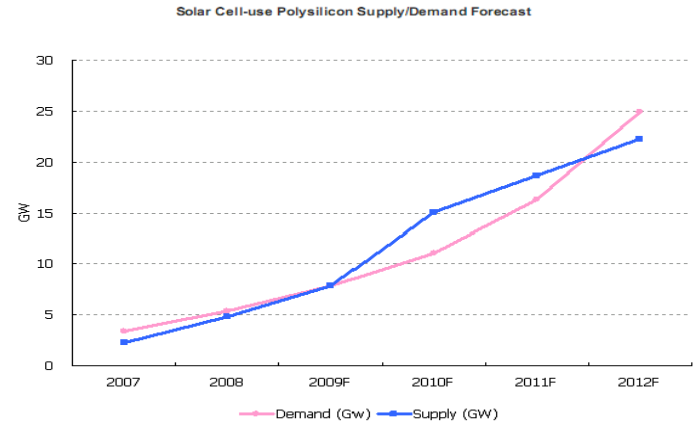
By the end of 2008, Chinese PV power installation capacity reached 140MWp in total.

2) Propose to initiate the "China PV Upspringing Plan 2009-2012", in order to reach the targets ahead of time

No matter in light of the international PV power market development or Chinese PV industry scale and technology level to make an analysis, Chinese PV development planning targets listed above are conservative and retarding, which are not aligned with the fast PV power growth. It is suggested that the

Chinese government take the opportunity of international PV market shrinking and PV power price returning to its rational level, and start-up the "*China PV Up springing Plan 2009-2012*" with total installation capacity of 3.5GWp to reach the medium and long term development goals ahead of time.

The following figure shows that, in 2009-2012, the world PV market is in condition with supply over demand, among which the supply surplus in 2010 and 2011 reaches 36% and 15% correspondingly and in total of 6.4GWp. *"China PV Up springing Plan 2009-2012"* can provide a market with about 3.5GWp, which is three times of 2008 PV modules production (1,270MWp, 19.84% globally). This plan can assist the Chinese PV industries in time and also reach the production target of RMB 1 /kWh presented by China PV industry [1][9][10][11].



	2007	2008	2009F	2010F	2011F	2012F	CAGR
Demand (GW)	3.4	5.4	7.8	11	16.3	24.9	49%
Supply (GW)	2.3	4.8	7.9	15	18.7	22.2	58%
Supply (K metric tons)	*20.7*	*40.2*	*61.5*	*108.3*	*128.7*	*144.4*	*47%*

(Source: Displaybank, "Solar Cell-use Polysilicon, Ingot and Wafer Technology and Market Trend")

DisplayBank 2009-01-16

Fig 7-1 Relation between PV supply and demand in the world

The market types and annual installation capacities in *"China PV Up springing Plan 2009-2012"* are shown in Tab 7-2. In *"China PV Up springing Plan 2009-2012"*, new installation capacity is 3,500MWp, of which 3,025MWp is grid-connected PV power systems (including emergence PV power), accounting for 86% of the total, bringing Chinese PV power technology into the mainstream of the world.

According to the schedule in Tab 7-2, *"China PV Up springing Plan 2009-2012"* will bring PV power system installation capacity up to 1790MWp in total by the end of 2011 and ahead of time achieve the development goal as 1,800MWp by 2020 in "*China RE Medium and Long Term Development Plan*", in which the total installation capacity during 2009-2011 is 1,650MWp, over 3

times of 500MWP as targeted in *"China PV Up springing Plan 2009-2012"*.

Tab 7-2 *"China PV Up springing Plan 2009-2012"* market types and the shares

Project types		Annual installation capacity (MWp)					Market share (%)				
	Year	2009	2010	2011	2012	total	2009	2010	2011	2012	total
A	Non-electrified area electrical power construction program	20	100	150	100	370	16.7	20.0	14.6	5.4	10.6
B	Open field grid-connected PV power plant	60	250	600	1000	1910	50.0	50.0	58.3	54.1	54.6
C	Urban grid-connected PV systems	20	80	150	500	750	16.7	16.0	14.6	27.0	21.4
D	PV Emergence power sources	15	50	100	200	365	12.5	10.0	9.7	10.8	10.4
E	Urban and rural PV lighting	5	20	30	50	105	4.2	4.0	2.9	2.7	3.0
	Total	120	500	1,030	1,850	3,500	100.0	100.0	100.0	100.0	100.0

"China PV Up springing Plan 2009-2012" includes some specific parts as below:

(A) Non-electrified area electrical power construction program can solve the power supply problem with herdsman and farmers in west and no-electricity areas, implement power supply to villages and all households therein, and will consider the potential capacity expansion in the SDDX project and proceed with "PV power alleviation pilot project". PV installation capacity will be 20MWp in 2009 and 370MWp totally during 2009-2012.

(B) Open field grid-connected PV power plant -such projects will be mainly implemented in open areas such as deserts, Gobi, unoccupied hill slopes and wasteland for the purpose of power generation and electricity transmission. PV installation capacity will be 60MWp in 2009 and 1910 MWp totally during 2009-2012.

(C) Urban grid-connected PV systems - will be mainly built in urban public and large-scale building roofs. PV installation capacity will be 20MWp in 2009 and 7500 MWp totally during 2009-2012.

(D) Emergence power sources for Emergence response institutions and places in large and middle cities – are mainly the low voltage side grid-connected PV power systems with battery bank. The Emergence PV installation capacity will be 15MWp in 2009 and 365 MWp totally during

2009-2012.

(E) "PV lighting" projects in large and middle cities and new village development-"two million PV lamps project" - the 100,000 PV lamps will be installed with total capacity of 5MWp in 2009 and 105 MWp totally during 2009-2012. Total installed PV lamps will be 2 million, shortened as "Two million PV lamps project".

3) *"China PV Up Springing Plan 2009-2012"* project investment and cost estimation

In accordance with the guideline of NDRC on RE development plan, the fund sources for PV power projects should be solved according to the project implementation area, construction scale, technical characteristics and development level, by the diversified models of investment by the state and the society. In the "*Energy Prosperity Plan (2009-2011) (draft)*", it was specified that central finance grants subsidies, governments verifies the tariff. The over flow part that exceeds over the local fired power tariff will be integrated into the renewable energy power cross-subsidy sharing mechanism. In Tab 7-2, in the projects listed in "PV Upspringing Plan 2009", the three major categories of non-electrified area electrical power development program, Emergence PV power sources, and urban PV lighting system are all the commonwealth projects which are subsidized by the government. with regard to the grid-connected projects, no matter the open field or the urban roofing PV power systems, the commercialized models of operating and construction shall be implemented with the tariff subsidies, or with the governmental investment side subsidy at the initial date of the construction, or with lessened operation tariff subsidy, or without the tariff subsidy at all.

With the technology advance and market scale expansion in PV industry, the initial investment cost and feed-in tariff with PV power system will be continually reduced, while conventional power sources tariff is increasing year by year. Such a tariff gap should be filled by the subsidies from the renewable energy tariff add-in by national grid according to related laws, rules and regulations.

2009-2012 PV feed-in tariff and subsidies are summarized in Tab 7-3, which are estimated on the basis of 2009 open field grid-connected PV power feed-in tariff of RMB1.4/kWh and based on grid-connected PV power feed-in tariff target of RMB 1 /kWh in 2012, and the conventional power tariff is RMB 0.5 /kWh in 2009, with 5% increment annually.

Tab 7-3 Open field grid-connected PV system cost and feed-in tariff and subsidy estimation

Year	2009	2010	2011	2012
PV module price (RMB/ Wp)	15	13	11.5	10
Grid-connected PV system construction cost (RMB/Wp)	20	18	16.5	15
Grid-connected PV power feed-in tariff (RMB/ kWh)	1.40	1.20	1.05	1.00
Conventional power feed in tariff (RMB/kWh)	0.50	0.53	0.55	0.58
Subsidy of tariff (RMB /kWh)	0.90	0.68	0.50	0.42

In Tab 7-4 are listed with "*PV Upspringing Plan 2009*" PV system initial investment cost and annual investment by type, the cost estimation is based on the data of "open field grid-connected PV power system" initial cost shown in Tab 7-2 and Tab 7-3, where additional investment of equipment of the off-grid PV systems with batteries and PV lighting systems over the other grid-connected PV systems are deemed as constant.

With considering the 4 years of implementation of "*PV Upspringing Plan 2009*", the relevant industries and technology for BIPV projects are not able to reach the level of large-scale application. "Urban grid-connected PV systems" will mainly install PV panel on the roof of buildings, whose system constitution is similar to "Open field grid-connected PV power plant", and the BIPV system with higher cost only accounts for small percentage, therefore in Tab 7-4, the same value is used in the estimation of the initial building cost between "Urban grid-connected PV systems" and "Open field grid-connected PV power plant" with estimating the total investment.

Tab 7-4 PV system initial investment cost by type and investment estimation in "*PV Upspringing Plan 2009*"

		PV system initial investment cost estimation (RMB /Wp)				"PV Upspringing Plan 2009" total investment estimate (RMB 100 million)				
	Year	2009	2010	2011	2012	2009	2010	2011	2012	Total
A	Non-electrified area electrical power construction program	30.0	28.0	26.5	25.0	6.0	28.0	39.8	25.0	98.8
B	Open field grid-connected PV power	20	18	16.5	15	12.0	45.0	99.0	150.0	306.0
C	Urban grid-connected PV systems	20	18	16.5	15	4.0	14.4	24.8	75.0	118.2
D	PV Emergence power sources	30.0	28.0	26.5	25.0	4.5	14.0	26.5	50.0	95.0
E	Urban and rural PV lighting	50.0	48.0	46.5	45.0	2.5	9.6	14.0	22.5	48.6
	Total	//	//	//	//	29.0	111.0	204.0	322.5	666.5

In Tab 7-4, the implementation of "PV Upspringing Plan 2009" with installation capacity of 3.5GWp PV power requires a total investment of about RMB 67 billion. The total investment of non-electrified area electrical power program, Emergence PV power sources and urban and rural PV lighting shall be financed by government, with about RMB 24 billion in total.

The total investment during 2009-2012 is about RMB 34.4 billion, 15% more than the RMB 30 billion as in "*National Energy Prosperity Plan (2009-2011)*" proposed by NEA, the total installation capacity is 1,650MWp, twice more than the proposed.

7.2 370MWp non-electrified area electrical power program

1. Launch the implementation of "SDDC" and "SDDH"

Through the implementation of "SDDX", other international cooperation projects, grid extension, the no-electricity population in remote and poor rural area had lowered a great scale. In "*RE Development 11th 5-year Plan*" and "*RE Medium and Long Term Development Plan*", it is brought up that the one million no-electricity households power supply issue in the remote rural area shall be solve by PV power systems and the small scale PV system. The target in "*Energy Prosperity Plan (2009-2011)*" made by NEA is to solve the problem of power supply for 2.3 million families. The average rural per capita electricity consumption shall reach 200 kWh or above, and about 2 millions families

should be electrified by PV.

With the current financial crisis, it is recommended to implement "SDDC" and "SDDH" projects as soon as possible, with strength and faster schedule, so as to reach the goal ahead of time. Supposed that the per capita 50kWh electricity consumption each year (1/4 of that in the "*Energy Prosperity Plan (2009-2011)*"), 3.5 people per family, the PV power installation capacity will reach 440MWp, with 800 hours annual effective hours. If calculated with 200kWh, the total installation capacity will be reaching 1750MWp.

2. SDDX project improvement and power capacity extension

Although "SDDX" project solved the basic power supply for the government-oriented village, only used in lighting, TV, and other basic electricity needs. With the rapid development of the society, livelihood of the people have been improves very much, in the remote area, the electrical appliances used and bought by the families in remote are getting more and more widely. The electricity use is increasing in a great extend and the PV power plants in SDDX project in 2002-2003 can satisfy the local electricity needs.

It is recommended that an overall maintenance and mid-term technical service be implemented for SDDX project so as to properly enlarge the capacity, to improve the equipments, and to enhance power supply capacity and quality. In SDDX project, the total installation capacity is 19.6MWp (including the wind-PV hybrid power systems), and with a number of household PV systems and a series of PV power projects, the accumulative installation capacity reached about 40MWp [2]. According to the current situation of power supply, electricity use requirement, developing prospect, original design capacity for meeting the basic demand of electricity such as lighting and TV-watching, considering the principle of same tariff for same quality power from the grid, it is recommended that 25% of capacity expansion should be done with newly installed PV power installation capacity of 10MWp.

3. Implement the "PV Project Poverty Alleviation" Pilot

Propose all levels of the governments to carry out the "*PV Poverty Alleviation Pilot*". In the areas where PV grid-connecting is accessible, by encouraging the remote, poor, and minority nationality areas to self-raise the fund, and with the aid of national grants, grid-connected PV power systems can be built, the electricity is generated and supplied to the grid according to the law, the legal tariff subsidy can be looked as the fixed income of the poor families. For example, A 2 kWp household PV system can generated and

supply power of about 3,000kWh, and based on 2009 grid-connected power tariff difference subsidy RMB 1.4/ kWh, the household can have tariff subsidy of about RMB 4,200 per year.

In addition, it is suggested that if "*PV Poverty Alleviation Pilot*" implementation during 11th 5-year period of time, with 10,000 poor households across China, PV installation capacity of about 20MWp will be widely considered, the annual tariff subsidy expenditure by the nation will be RMB 27 million (based on feed-in tariff in 2009).

7.3 2,660 MWp scale grid-connected PV power program

1. Large-scale PV grid-connected systems are the supports of Chinese sustainable PV industry development.

Launching of the large-scaled grid-connected PV power projects can raise the Chinese PV industry to a new level, so as to assure the sustainable development of the PV market in China. The large-scaled desert PV power plants and the urban building integrated grid-connected power system have been planned in "*Chinese Renewable Energy Medium & Long Term Development Plan*" and "*Chinese RE Development 11th 5-year Plan*", by 2010, the installation capacity will reach 100MWp, and by 2020, the installation capacity will reach 1200MWp. It is proposed that "*PV Upspringing Plan 2009*" large-scaled grid-connected project shall be launched as soon as possible, including open field PV power plants and urban grid-connected PV pilot projects, with a total installation capacity of 2,660MWp. This plan is good and beneficial news for Chinese PV industry being in troubles.

With governmental subsidies according to the relevant policies, the grid-connected PV power projects can be operated commercially, By referring to the bidding of concession wind power, the measurements of PV power project shall be made out as soon as possible, so as to speed up the launching of the large-scaled grid-connected PV power project in China and to reach the targets. In recent years, the scale of Chinese PV power industry has been enlarged quickly, the technology has been improved, and cost is lowered much. Under the serious conditions of global financial crisis, international market shrinkage, and supply over demands, after the price-competing and the floating profit reducing in the producing stage, through the jointly efforts of producers, system integrators, dealers, and consumers, along with strict and scientific management and maintenance, and the preferential policy on loan, tax, and land use, by 2012, the target that the on-grid PV power feed-in tariff reach RMB 1/kWh or below can be attained surely.

In 2008 NDRC's approval letter for Shanghai and Inner Mongolia PV grid-connected power systems, feed-in tariff was RMB 4 /kWh and the document for DunHuang 10MWp large-scaled gird-connected project bidding clearly stated that the bidding price can not exceed over RMB 4/kWh. However, in the Dunhuang 10 MWp PV power project bidding on Mar, 2009, the average of 13 valid bidders was RMB 1.42/kWh and the highest bid was less than RMB 2/kWh, it is a cheering good sign. The average of the lowest three valid bids was RMB 0.98 /kWh, and the lowest was RMB 0.69 /kWh. This shows that it is very possible for the feed-in tariff of gridded PV power to be lowered than RMB 1 /kWh, and the RMB 1/kWh target is achieved three years ahead. That means, the originally budget can extend the scale for 3 times.

"*PV Upspringing Plan 2009*" grid-connected system scale and cost estimation are shown in Tab 7-5. The PV power system construction cost and the price listed below are calculated according to the Tab 7-3. It can be seen from Tab 7-5 that by 2012, 2,660MWp grid-connected PV systems will be installed and put into operation, the open field grid-connected PV power plants and the urban grid-connected PV power system shall be operated commercially, by carrying out the tariff subsidy, the total of subsidy for PV grid-connecting power will be RMB 1.8 billion per year.

Tab 7-5 "*PV Upspringing Plan 2009*" grid-connected PV power system scale and cost estimation

year	2009	2010	2011	2012
Initial system investment cost (RMB/Wp)	20.00	18.00	16.50	15.00
PV grid-connected power tariff (RMB/ kWh)	1.40	1.20	1.05	1.00
Conventional power tariff (RMB/ kWh)	0.50	0.53	0.55	0.58
Tariff subsidy (RMB/ kWh)	0.90	0.68	0.50	0.42
Annual installation capacity （MWp)	80.0	330.0	750.0	1500.0
Accumulative installation capacity (MWp)	80.0	410.0	1160.0	2660.0
Annual new power generation **(100 million kWh)	1.12	4.63	10.65	20.50
Initial system investment cost (RMB 100 bn)	16.00	59.40	123.75	225.00
Current year new tariff subsidy in total (RMB 100 mio)	1.01	3.13	5.31	8.63
Current year tariff subsidy expenditure in total (RMB 100 mio)	1.01	4.14	9.45	18.08

*： Conventional power tariff is based on the 5% yearly growth.

**：The calculation of PV system power generation: Open field on-grid PV power

effective operation time is 1500h/year, and urban PV power grid-connecting effective operation is 1100h/year.

2. The regional allocation of the open field PV power plant and the urban grid-connected PV power system

1) Scenarios of the scale of implementation in different areas

"PV Upspringing Plan 2009" open field PV power plants will have the total installation capacity of 1,910MWp and urban grid-connected PV system installation capacity of 750MWp, and the total is 2,660MWp. The allocation scenario is as follows,

- **Western area**: desert areas and other open fields gird-connected PV power 1,510MWp. Urban grid-connected PV pilot project serves 20MWp, in total of 1,530MWp.
- **Eastern areas**: waste land and hill slope in eastern open areas with grid-connected PV system of 370MWp, and urban grid-connected PV system to be 670MWp, in total of 1,040MWp.
- **Other areas:** open field grid-connected PV system of 30MWpand urban roof pilot system with 60MWp, in total of 90MWp.

With considering the conditions of the local geographical environment, solar energy resources, development level of economy, digestion of the load capacity, and the support from the central and local governments to implement PV power shall be considered integrated, the allocation of regional PV power is shown in Tab 7-6.

Tab 7-6 Scale allocation scenario grid-connected PV power in "*PV Upspringing Plan 2009*"

Unit: MWp

Region	No	Province	Open field grid-connected PV power plant capacity	Urban grid-connected PV power capacity	Total
West region	1	Inner Mongolia	500	10	510
	2	Gansu	300	3	303
	3	Ningxia	200	1	201
	4	Qinghai	180	1	181
	5	Xinjiang	150	1	151
	6	Yunnan	100	2	102
	7	Tibet	50	1	51
	8	Shanxi	30	1	31
Total in west region			1,510	20	1,530
East region	1	Hebei	180	60	240
	2	Beijing	50	80	130
	3	Tianjin	40	50	90
	4	Liaoning	30	30	60
	5	Shandong	20	40	60
	6	Guangdong	20	35	55
	7	Shanxi	15	10	25
	8	Hainan	10	15	25
	9	Jiangsu	2	200	202
	10	Zhejiang	2	50	52
	11	Shanghai	1	100	101
Total in east region			370	670	1,040
Total areas			30	60	90
Total			1,910	750	2,660

2) PV grid-connected stations in the open fields: west region-1,510MWp. East region and other regions-400MWp

The total of desert, deserted areas, and semi-desert areas in China is about 1.08 million square kilometer. Those areas are located mainly in the western provinces with rich solar energy resource. In the future of solar power, those areas will become the power generation base in China. In the "*RE Development 11th 5-year Plan*", it was present to build the large-scaled PV power plant in the desert areas. In the "*RE Medium and Long Term Development Plan*", it was estimated that, by 2020, the total desert area PV power capacity will reach 200MWp.

It is suggested to build 1,510MWp open field PV power plant in western

eight provinces, scale each province can be ranged of 30-500MWp. Based on 50MWp PV power/ km^2 land area, 1,510 MWp grid-connected PV power system needs 32 km^2 area. The existing large hydro-power station can be used to as energy storage and adjustment plant for the PV power plant; and by using the electric power transmission lines of the "*West Power Transmittal to the East Program*", the management and the dispatching of the electrical system can be achieved. Meanwhile, pumped storage power station in the areas with appropriate conditions can be built, which can make best use of the PV power, and can set the solid foundation and the conditions for future grid-connected PV power. For example, in Tibet, there are Yang Bajing geothermal power plant and Yanghu pumped storage plant, where is of high latitude and rich solar energy, PV power can be developed in large scale, as a power generation base in Tibet, in order to solve the issues of power supply in Tibet.

In the eastern areas of China, plenty of non-cultivated lands are available, including waste hillsides and land; especially there are lot of deserted areas in northern China. In these areas, the people live concentrated; with certain scale of economy and the production activities, and it is the main electrical power load areas, where the solar energy resource is very rich as well. Herein an example, the solar irradiation in Weihai,, Shandong is 1,627kWh/m^2, more than that in Lanzhou of 1,514kWh/m^2, almost equalize 1,654kWh/m^2 in Yinchuan. By utilizing the waste land to build PV power system can make use of the solar energy in the local. In those areas, the grid capacity is relatively big, and the large scale grid-connected PV power has little impact on the grid. Meanwhile, the other positive factors can be activated in order to gain the experiences, to strengthen the awareness for PV power, and to promote the overall development of the PV market.

It is recommended to build PV power station with 400MWp in the waste hillside and waste land in eastern provinces. The provinces in northern China, southern China, and eastern China, can be chosen in priority. The building scale of PV power can be determined according to the solar radiation, the geographical and topographical conditions, and the economical development level. Because of the advantages the technology, economy, and traffic etc, the 400MWp large-scale grid-connected PV power project can be planned in priority and implement as early as possible, as the experiences are learned, it shall be spread over, and with making out other relevant practical policies.

3) Urban grid-connected PV systems: east region-670MWp, west region-20MWp, other regions-60MWp

Urban construction and building integrated PV power grid-connected system is the main application for PV power. Under the current technical condition, the main type of urban grid-connected PV power system is the PV roof system. Chinese PV industries are concentrated in eastern provinces, and the PV industry plays an important role in the local economic development. The economy is developed in eastern area and the local governments are enthusiastic in developing local PV power application, and also have the wills to develop and support the PV industry in the local. Building urban roof PV system and BIPV is a brilliant way to show the cities' appearance of the cities and achievements of the local government, in eastern areas there are the full political, economical and social conditions to build the PV roof grid –connected power system. In the "*RE Development 11th 5-year Plan"* and *"RE Medium and Long Term Development Plan*", by 2010, the roof PV system is over 1000 sets, in total of a capacity of 50MWp; by 2020, 20 thousands sets will be built with a total capacity of 1GWp.

It is recommended to build 670MWp grid-connected PV system in eastern cities, with the majority of the large building roofs, such as stadiums, galleries, museums, traffic stations, factories, universities, high schools, governmental buildings and some of the residential area buildings. Urban roof PV system is normally low voltage power system. The electricity is generated and consumed locally. The system equipped with energy storage battery can serve as Emergence backup power supply source. Urban grid-connected PV system can also be developed into smart grid system, which can charge the electric vehicle and other load of energy storage in a day. The grid-connected PV system, close to the electric power load, and in accordance with the load in time, has the capability of peak regulating and the electricity quality improving at the end of grid. It is of favorable economic and social benefit.

It is recommended in western cities to build small quantity of the pilot roof PV systems, with a capacity roughly about 20MWp, and other cities PV power grid-connected system with about 60MWp.

7.4 365 MWp Emergence response PV power supply source program

1. Emergence power supply boosts the hope and confidence for the people in disasters

At the beginning of 2008, a rarely snow storm swapped southern areas in China; and in May 12, 2009, a massive earthquake attacked the southeastern China, buildings are destroyed and collapsed. As the catastrophe occurred, all the traffic, electric supply and communications are all cut off at once. All of a

sudden, everyone in the disaster area fell into darkness and fears. Emergence power supply can play a key role when the normal power supply is off, so as to ensure the electricity supply of communication, first aid and refuges.

Since Nov 1, 2007, "*PRC Emergence Affair Response and Tackling Law*" was put into force in China and "*PRC Emergence Response Solution Public Measures*" was issued by central government on Jan, 2006, and "*the 21 Emergence Measures for Incidents Public Accidents*" were released as well, in order to dispose in time, reduce the loss, and ensure the safety. Local governments were also taking actions for Emergence systems building and reduce the loss due to the disaster to the lowest degree. In the inhabitants centralized areas, building shelters can provide temporary domiciles for the people in calamites, for the next settlement. These kinds of Emergence shelters shall be equipped the basic living facilities such as lighting, communication, radios, beds, etc; the electricity supply is the most important presupposition.

2. Launch Emergence PV power sources project, improve Emergence response system

Now, the widely installed conventional power supply sources include EPS and diesel generators. EPS have small capacity and limited power supply duration; the diesel generators need to store backup fuels and it is idle in normal time, if without appropriate maintaining, it is unreliable to start up to supply power in time. With regard to PV power, with the advantages of unlimited solar energy resource, no pollution emission, being safe and reliable, free of maintains, PV power system does not rely on normal power supply. PV power system can be integrated into buildings, or installed at the urban Emergence shelters. In normal time, the green electricity can be supplied to the gird or use by itself, and can supply emergence basic electricity as the grid is off.

In terms of the emergence and shelter facilities concerned with the public safety and the safety of people's life and property, the local government shall take actions as soon as possible, start the construction of PV emergence power system, so as to set up the security system for the city. On the other hand, under the situation of financial crisis, Chinese PV industry is in difficulties, the Emergence PV power system project prompt starting–up will be helpful to the Chinese PV industry, and help Chinese PV industry out of the plight.

In order to support the implementation of the Emergence system and shelter PV power supply program, the project research team has drafted

"***Guideline on Implementation of the Emergence System and Shelter PV Power Supply Program***", see appendix 10.4.

3. Launch "PV Upspringing Plan 2009" 365MWp Emergence PV power sources project

Emergence PV power supply systems are mainly applied in the large and medium size cities. The place where is suitable to install the PV emergence power supply system includes: emergence response center, fire fighting center, power utilities, water works, gas company, earthquake, civil defense, post office, TV and broadcasting station, mobile communication, railway station, airport, hospitals and other sites. As a public measure, the PV power system should be built into Emergence shelters first.

The emergence PV power supply system can be designed to be power supply with a storage battery low voltage grid-connected PV power system, in order to make use of the advantage of the flexibility and distribution of the PV system, the capacity does not exceed over 50KWp. Because of the mature technology, plenty experiences in design, installation and commissioning, lot of supplier of the equipment, the product quality assurance, as the project is launched, standard designed can be carried out, and the project can be deployed in large scale soon.

China is in the accelerating stage of urbanization. According to the report of State Statistics Bureau, by 2007, there are 237 cities in China with the urban population of over 500,000, in which 119 cities have the population of over one million. The urban and township population is 594 millions in China, accounting for 44.9% (Report No. 7 for "*Opening and Reform 30 years*": *rapid urban economic and social development*)[1]. Accordingly, the emergence shelter should have a capacity of 200 million people. (33% of the urban population). With considering the unit PV power supply capacity as 5Wp, the total installation capacity can reach 1.0GWp.

It is recommended to start-up the emergence system and shelter PV power supply projects in "PV Upspringing Plan 2009" as soon as possible. The total installation capacity may approximately be 365MWp.

In Tab 7-7 is listed the suggested arrangement and cost estimation for "PV Upspringing Plan 2009" emergence PV power supply project. In Tab 7-7, the estimation of the investment and the subsidy are calculated according to the data in the Tab 7-3 and 7-4. The initial investment is about RMB 9.5 billions. If the central finance subsidizes 20% of the investment, the budget will be RMB

[1] Source: State Statistics Bureau Website, 2008.11.04 http://www.stats.gov.cn/

1.9 billions.

Following the principle of normal use and emergent use, normally, the emergence PV power system can be connected into the grid and supply power to grid, according to the "Renewable Energy Promotion Law" and relevant policies. The subsidy will be RMB 180 million each year if the total installation PV power capacity of 3,650 MWp can be put into use fully by 2012.

Tab 7-7 "PV Upspringing Plan 2009" Emergence PV supply system implementation plan

Year	2009	2010	2011	2012
System initial investment cost (RMB/Wp)	30.00	28.00	26.50	25.00
PV feed-in tariff (RMB/kWh)	1.40	1.20	1.05	1.00
Conventional power feed-in tariff (RMB/kWh)	0.50	0.53	0.55	0.58
Tariff subsidy (RMB/kWh)	0.90	0.68	0.50	0.42
Annual installation capacity（MWp)	15.0	50.0	100.0	200.0
Accumulative installation capacity（MWp)	15.0	65.0	165.0	365.0
New increased power generation (100million kWh)*	0.15	0.50	1.00	2.00
Initial construction general cost (RMB 100 mio)	4.50	14.00	26.50	50.00
Central government subsidy 20% (RMB 100 mio)	0.90	2.80	5.30	10.00
That year increased total of tariff subsidy (RMB 100 mio)	0.14	0.34	0.50	0.84
That year total expenditure for tariff subsidy (RMB 100 mio)	0.14	0.5	1.0	1.8

*：PV power generation is calculated based on effective operation 1000 hours annually.

7.5 Two million PV lamps urban and rural PV lighting project with 105 MWp

1. Fast growing PV lighting market

Solar PV lighting includes solar powered street lamps, garden lamps, lawn lamp, landscape lamps, signal indicator lights, and advertisement lighting etc, is the important part of PV application market. In 2007, the annual consumption of the PV lighting and other PV product reached 40MWp. The PV lighting products domestically installed in 2007 (street lamp, lawn lamp, landscape lighting, LED lighting, traffic signals) already reached 6MWp, which accounts for the 30% of total installation in 2007.

The appearance of new energy saving lighting sources such LED lighting makes the market of solar lighting (mainly street lamp, lawn lamp) increases

rapidly, and is putting into implementation for much urban and rural construction. For example, since 2006, Beijing had implemented the "Lighting up" project to install about 100 thousands solar powered street lamps, with a total installation of 600 million dollars. About 100 thousands solar powered lamps, garden lamps, lawn lamp and signs had been installed around Beijing. In other provinces and cities, solar powered street lamps and new, high-brightness LED lighting, and relative urban lighting and landscape projects should be largely promoted.

Solar powered lighting is becoming a new growing point for PV market for the recent years.

2. The market scale of the solar powered lighting is huge

PV lighting is widely applied to urban and rural various fields, such as rural roads, villages, urban roads and streets, residential communities, public roads, bridges and tunnel illumination. Urban streets and residential lightings are operated by the utility system, without involvement with any individuals or departments, which is prone to operate. PV lighting in rural areas is free of charges for the use of electricity, and largely welcomed. According to the Chinese renewable energy development plan, PV lighting should be favorable in the projects of urban traffic lighting and landscaping lighting. By 2010, the solar powered street lamps and garden lamps should have a capacity of 5MWp accumulatively; by 2020, the total will be 50MWp.

By 2007, the total length of the highway in China is about 3.6 million kilometers, which includes 53900 kilometers [1]. According to the statistic bulletin, by 2007, China has urban streets of 246,000 km, the county downtown streets of 83800 kilometers [2]. If calculated according to 50W lamps every 50 meters interval, and in 5% highway, 20% express way, and all the urban and county downtown streets PV lamp will be installed, about three million PV lamps are needed, with about 300MWp solar cell. With the increasing of the nation economic strength and the living level of the people, the mileage and the brightness in the streets that needs to be lightened will increase correspondingly. The brightness is needed to be increased in a large scale as well. With considering the new roads, streets and residential areas, and the lighting requirement of new village building, the PV market potential will be very large.

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[1] China Statistical Year Book 2008, http://www.stats.gov.cn/tjsj/ndsj/2008/indexch.htm

[2] Ministry of Housing and Urban-Rural Construction of the People's Republic of China, www.mohurd.gov.cn, June.24th, 2008

3. Launch "2 million PV lamps with 105MWp urban and rural PV lighting project" as soon as possible

It is recommended to implement the "Solar PV Street Lamp Project" in the "*Renewable Energy 11th 5-year Development Plan*" as soon as possible. Promote the application of PV lighting system in city and implement "PV lighting project" in rural areas with integrating the *New Village Construction;* enlarge the application scale, by installing two million PV powered lights during 2009-2012, with a total of 105MWp. The project of PV lighting shall be started in large & medium sized cities and suburb villages, gradually spread to the small cities and town. Installing PV lighting system in cities and township will a green project which are beneficial to the society and the people. This green project would widely be supported and welcomed.

The PV lighting system can be designed with various technological schemes and operated in different ways. Off-grid system can be considered, gird-connected power system can also be used to ensure the reliability of the power supply. The power supply can be the format of one lamp to one PV system or the street lamps powered by PV power system. The large scale urban PV lighting system can mitigate the power supply peak pressure at night, which exerts the power supply peak regulation.

With regard to the implementation of the PV lighting project, the following s shall be considered comprehensively: the solar resources, economic level, geographical circumstances, supporting strength and enthusiasm of the local government. Fig 7-8 listed the implementation scaled and the schedule. The numbers of lamps are calculated with 50W per lamp.

Tab 7-8 "*PV Upspringing Plan 2009*" lighting project -"two million PV lamps with 105MWp project" implementation scale and the schedule

No.	Province	PV lighting project capacity（MWp）					Number of PV lamp (10 thousand sets)				
		Total	2009	2010	2011	2012	Total	2009	2010	2011	2012
1	Beijing	9.3	0.3	2.0	3.0	4.0	18.6	0.6	4.0	6.0	8.0
2	Shanghai	8.5	0.5	3.0	2.0	3.0	17.0	1.0	6.0	4.0	6.0
3	Tianjin	8.8	0.3	2.0	2.5	4.0	17.6	0.6	4.0	5.0	8.0
4	Hebei	9.4	0.4	2.0	3.0	4.0	18.8	0.8	4.0	6.0	8.0
5	Inner Mongolia	3.1	0.2	0.4	1.5	1.0	6.2	0.4	0.8	3.0	2.0
6	Ningxia	1.4	0.05	0.2	0.4	0.7	2.7	0.1	0.4	0.8	1.4
7	Shanxi	2.0	0.05	0.2	0.5	1.2	3.9	0.1	0.4	1.0	2.4
8	Liaoning	2.4	0.1	0.3	1.0	1.0	4.8	0.2	0.6	2.0	2.0
9	Jilin	0.6	0.05	0.1	0.1	0.3	1.1	0.1	0.2	0.2	0.6
10	Hei Longjiang	0.6	0.05	0.1	0.1	0.3	1.1	0.1	0.2	0.2	0.6
11	Shandong	10.4	0.2	1.2	3.0	6.0	20.8	0.4	2.4	6.0	12.0
12	Jiangsu	9.3	0.3	2.0	3.0	4.0	18.6	0.6	4.0	6.0	8.0
13	Zhejiang	3.0	0.1	0.5	1.0	1.4	6.0	0.2	1.0	2.0	2.8
14	Fujian	1.9	0.1	0.3	0.5	1.0	3.8	0.2	0.6	1.0	2.0
15	Anhui	1.9	0.1	0.3	0.5	1.0	3.8	0.2	0.6	1.0	2.0
16	Jiangxi	1.9	0.1	0.3	0.5	1.0	3.8	0.2	0.6	1.0	2.0
17	Hubei	1.9	0.1	0.3	0.5	1.0	3.8	0.2	0.6	1.0	2.0
18	Henan	2.9	0.1	0.3	0.5	2.0	5.8	0.2	0.6	1.0	4.0
19	Chong Qing	0.3	0.05	0.05	0.05	0.15	0.6	0.1	0.1	0.1	0.3
20	Hunan	0.6	0.10	0.1	0.2	0.2	1.2	0.2	0.2	0.4	0.4
21	Yunnan	0.9	0.10	0.2	0.3	0.3	1.8	0.2	0.4	0.6	0.6
22	Sichuan	0.6	0.05	0.2	0.1	0.2	1.1	0.1	0.4	0.2	0.4
23	Guizhou	0.2	0.05	0.05	0.05	0.05	0.4	0.1	0.1	0.1	0.1
24	Guang Dong	12.2	0.2	2.0	3.0	7.0	24.4	0.4	4.0	6.0	14.0
25	Hainan	3.2	0.2	0.5	0.5	2.0	6.4	0.4	1.0	1.0	4.0
26	Guangxi	0.7	0.1	0.1	0.2	0.3	1.4	0.2	0.2	0.4	0.6
27	Xinjiang	1.9	0.2	0.3	0.5	0.9	3.8	0.4	0.6	1.0	1.8
28	Gansu	2.8	0.3	0.5	0.8	1.2	5.6	0.6	1.0	1.6	2.4
29	Qinghai	1.0	0.2	0.2	0.3	0.3	2.0	0.4	0.4	0.6	0.6
30	Shanxi	1.0	0.2	0.2	0.3	0.3	2.0	0.4	0.4	0.6	0.6
31	Tibet	0.5	0.1	0.1	0.1	0.2	1.0	0.2	0.2	0.2	0.4
Total		105.0	5.0	20.0	30.0	50.0	209.9	9.9	40.0	60.0	100.0

4. Urban and rural PV lighting project implementation scale and cost estimation

"Two million PV lamps project" scale and cost estimation are shown in Tab 7-9, in which the required investment and subsidy is calculated on the basis of the data in Tab 7-3 and Tab 7-4. It can be seen that by 2012, a total of 105MWp PV lighting system should be installed, with total cost of RMB 5 billion.

The fund of the "Two million PV lamps project" is mainly sponsored by the local governments, with 20% fiscal subsidy by the central government, and the subsidy will be more preferential in the west. If central government grants 20% fund, central investment will be RMB 1 billion.

Tab 7-9 "*PV Upspringing Plan 2009*" two million PV street lamps lighting project implementation and estimation of cost

Year	2009	2010	2011	2012
System initial investment cost (RMB/Wp)	50.00	48.00	46.50	45.00
Annual installation capacity （MWp)	5.0	20.0	30.0	50.0
Accumulative installation capacity （MWp)	5.0	25.0	55.0	105.0
Total investment cost of initial construction (RMB 100 mio)	2.50	9.60	13.95	22.50
Fiscal subsidy by the central gov20% (RMB 100 mio)	0.50	1.92	2.79	4.50

Note: the PV power generation is calculated with 1000 effective hrs per year.

7.6 Summary

In order to speed up the Chinese PV industry development and tackle current financial crisis, the government shall launch relevant projects, help the PV industry to overcome the difficulties. .

In this chapter, the "China PV Upspringing Plan (2009-2012)" with a total installation capacity of 3,500MWp is presented. General estimation and the analysis are made and the implementation plan is brought out.

1. The technological and political condition of launching large scale PV industry is all ready, and is timely.
2. Base on the current international and domestic situation, the project scale and estimation of the investment for "*PV Upspringing Plan (2009-2012)* " were presented.
3. It is recommended to launch the government subsidizing and policies

supporting PV power project as soon as possible, so as to form the domestic PV market with a total 3,500MWp and the investment of RMB 67 billion. The total investment for 2009-2011 is about RMB 34.4 billion, exceeding 15% over that RMB 30 billion in the "*Energy Prosperity Plan (2009-2011)*" by NEA. The total installation capacity is 1,650 MWp, increased by twice of the 500MWp in the original plan.

Tab 7-10 "*PV Upspringing Plan 2009*" yearly investment plan and installation capacity

Year	2009	2010	2011	2012	total
Current year installation capacity （MWp)	120	500	1,030	1,850	3,500
Yearly investment (RMB 100 million)	29.0	111.0	204.0	322.5	666.45
Accumulative new increased installation capacity （MWp)	120	620	1,650	3,500	
Accumulative new increased investment (RMB 100 million)	29.0	140	343.95	666.45	

4. Projects, which shall be launched as soon as possible, include as follows:

   (1) Non-electrified area electrical power construction program, in 2009, installation capacity is 20MWp. The total installation during 2009 thru 2012 will be 370MWp.

   (2) Open field grid-connected PV power plant program. 60MWp in 2009, 1,910 MWp during 2009 - 2012.

   (3) Urban grid-connected PV system. 20MWp in 2009, 750MWp during 2009 - 2012.

   (4) Emergence PV power source. 15MWp in 2009, 365MWp during 2009-2012.

   (5) "PV lighting project". In 2009, PV lighting lamps with 10000, power capacity of 5MWp; in 2009-2012, total PV lighting lamps with 210 million, power capacity of 105MWp.

5. The main government-subsidizing PV projects include: non-electrified area electrical power construction program, emergence PV power source, urban and town grid-connected PV system, total investment is about RMB 24 billion. If the government subsidizes 50% of the non-electrified area electrical power construction program, emergence PV power source and urban and rural PV lighting project would be subsidized 20%. The total subsidy of four years is RMB 7.8 billion.

6. The tariff subsidized commercial projects include: 1) Open area

grid-connected PV power plant; 2) urban grid-connected PV system. In 2009-2012, the total installation capacity is 2,660MWp, with the total investment of RMB 43 billion.

7. Emergence PV power source and PV street lamp projects will be mainly financed by local fund. If the central government subsides 20%, the 4 years investment by central government will be RMB 2.9 billion.

References

[1] Ma Shenghong, Jiangsu PV industry survey report, Nov. 2008

[2] Zhao Yuwen, Wang Sicheng, et al, *Chinese PV industry development research report (2006-2007)* REDP PMO, Chinese Society of Renewable Energy, PV expertise Commission, Mar 2008.

[3] Wang Sicheng, *The counter measurements of tackling financial crisis and drive the domestic PV market*, Nov, 2008

[4] Zhai Zhigao, *The peril hidden solar PV industry*, solar energy industry alliance web, www.21tyn.com, Nov 17, 2008

[5] Zhongshang Info Web, The consultant report on financial crisis impact and *development strategy on the Chinese PV industry*, http://www.askci.com, Dec 2008

[6] Ma Shenghong, Start-up the internal demand to build the 2GWp PV *power plant, taking the PV as the Chinese strategic industry and backup energy- the proposal on the 4000 billion internal demand to promote the economy upgrading and sustainable developmen*t, Dec, 2008

[7] IEE, CAS, *Chinese 11th 5-year PV development plan proposed report*, May, 2005

[8] PRC NDRC, *RE 11th 5-year development plan*, Mar 19, 2008

[9] Xia Aiming, Li Hua, and Ma Shenghong, *In 2010, Chinese PV industry entering the period of self growing- Outlook for the global PV industry development,* Chinese Building Status – Solar Energy, Issue 4 of 2008, page 45-48

[10] Photon year forecasting report, *The True Cost of Solar Power:10 Cents/kWh by 2010,* Apr 2007

[11] Kiefer, Shadow under the sunshine: who can ignite the Chinese solar PV *industry?* IT World, www.ceocio.com.cn, Mar 21, 2007

[12] NDRC, *RE Medium & Long Term Development Plan*, Sep 4, 2007

[13] *PRC Emergence Affair Response and Tackling Law,* central government website www.gov.cn, Aug 30, 2007

[14] *PRC Emergence Response Solution Public Measures,* central government website www.gov.cn, Jan 8, 2006

[15] *The state special emergence response measures*, central government website www.gov.cn, Jan 11, 2006

[16] PRC State Statistics Bureau, China Statistics Year Book 2007

www.stats.gov.cn/tjsj/ndsj/2007/indexch.htm

[17] Zhang Yabin, Investigation and design on the emergence PV power supply used in the emergence shelter and systems, Jan. 2009

8. Study of Scale & Profit on “Chinese PV Market Development Plan 2009-2020”

8.1 Overview

The economic globalization brings about the developing opportunities for Chinese PV industry, such as advanced technologies, top talented personnel, capital, and the market etc; with relying on the oversea PV market, Chinese PV industry has developed very quickly, and won the international influence and position. However, the sudden global financial crisis, makes the Chinese PV industry, whose market and the raw material are oversea, seriously fall into pressures and menaces.

With regard to the PV industry in China, any fluctuations in foreign PV policy and market may set off huge waves to the domestic PV industry. The well-known Chinese PV companies listed abroad, and a huge number of companies are feed their financing hopes on the overseas capital market. Gloomy international economic environment has blocked the channels of financing abroad. Once the capital and the market closed the door at the time, a large number of domestic PV enterprises might be under shock, or even go extinction.

Today, Chinese PV enterprises are experiencing the severe winter, It is of importance for China how to support Chinese PV industry to get out of the dilemma.

Generally, the problems and the deficiencies of Chinese PV industry and PV market can be summarized as follows:

1) Being busy with the expanding may lead to the energy production surplus, and the vast investment venture.

2) The too small domestic PV market is the bottleneck of PV stably developing.

3) With the gradual advent of the international financial crisis impact, Chinese PV industry is facing tremendous pressures and menaces.

8.2 Guiding thoughts and the principles

1. Guiding thoughts

With being guided by *Deng Xiaoping Theory, “three represents” importance thought, and scientific development outlook*, by implementing the *China Renewable Energy Promotion Law,* focusing on the resources integrating and orderly exploiting, and improving the system innovation, consolidating the

management, optimizing PV industry layout, promoting industry upgrading by science and technology, cleanly producing and reasonably utilizing the favorable conditions and resources, and so on, the Chinese PV industry system and the market system shall be constituted, which will accord with the international and national circumstances, and it will make great strategic contribution to the Chinese energy and electric power sustainability.

2. Basic principles

1) Based upon the present, having the long run, planning as whole, the total quantity shall be controlled, stepping -on steadily, and developing harmoniously, the investment shall be kept from being over-heated locally .

2) Persisting on the harmonization among the market and economy and society. Not only stressed on large scale utilization of PV power is necessary, but also focused on the issues of rural no-electricity electric power construction. Thru the adjustment to local situation, rational planning, lay-out, and orderly developing shall be done, with being based on the local resources, economy, and the social situations.

3) Insisting the mutual promotion between market development and industrial development. In terms of the PV power project with great potentials and promising commercial prospect, the necessary measures shall be taken to enlarge the market demand, by increasing the investment; the sustainable and stable market demand of PV power shall provide the favorable condition for the PV industry. The technology R&D and industrial development system shall be established mainly based on the self innovation. The technologies and capacity building shall be speeded up; and through the sustainable and large scale development, the Chinese PV market competitive ability shall be reinforced, which will lay the foundation for the forthcoming PV large scale development.

4) Insisting on the combination of incentive policies and market mechanism. By incentive policies that the rural energy shortage and no-electricity will be solved by PV power, and that the State sets up the market system which will promote the PV market rational development. The enthusiasm of the investors will be activated by marketization means and macro adjustment and control, in order to promote and lift the technology level of PV power, cut down the cost, promote industrialization and to elevate the self market competitive ability. As the above measures are settled up to make the Chinese PV industry and market develop rapidly, readily, and greatly under the support of national policies.

5) By implementing the guidelines of sciences & technology develop-

ment, “Self innovation, stressing on the outreaching, supporting the development, and leading the future”, the PV sciences and technology innovation system, in which the enterprise is the main body, the market is the guide, and producing, studying and researching are tri-integrated, will be built and consummated. The development of the practical advanced technologies is in priority, the PV industrial scientific and technical level shall be improved; the frontal technologies shall be stressed to develop, so as to lay the foundation for the future PV development. It shall be insist that the near term technologies utilization and development shall be integrated with the far term technologies storage. The technologies, which have a certain market demand in the near term, meanwhile will have the big potentials in the future, shall be supported actively and powerfully.

6) Exerting the resources and regional advantages. The PV industry and PV market self-development ability and innovation ability shall be boosted up, in order to lift up the competitive ability and the international position of Chinese PV technology, industry, and market.

7) Stressing on the international cooperation. By making best of the chances of global renewable energy development, environmental protection, and emission reduction, the introducing of the technology, talented personnel, and the capital shall be sped up, in order to promote the Chinese PV industry and market development rapidly.

8) Science and technology, and the law knowledge dissemination shall be stressed, and the professional quality of the employees shall be lifted up, and the human resources in PV industry shall be exploited.

9) In terms of sources of capital: (1) financing principles: government guiding, market operating, attracting various investment, including international aid, so as to form the financing mechanism of diversification; (2) Channels of financing: central government, local government, civilian capital, international cooperation, self-raising by enterprises itself, bank-loan, etc.

8.3 Developing targets

Long term targets

a) Solar PV power generation will make great contributions to the Chinese energy and power structure optimization.

b) Solar PV power shall make great contributions to the safe, economical, environment-friendly, and sustainable energy supply system in China and with fully demonstrating the social and environmental benefits of the PV industry.

c) Follow the international trend of renewable energy power, in order to lift up the position and influence of China.

d) Change the current asymmetrical situation between PV market and the industry in China.

e) Make PV industry become an important component of Chinese tremendous economy growth, and promoting PV industry to formulate a new economy model entirely to become an increasing point of economy, to contribute to the economy sustainability.

f) In 2050, Chinese PV power generation will reach 20% of total electricity cross China, to be as one of the main energies in China.

Near term targets

According to the demand of assuring the power supply safety and optimization of power supply sources structure, the technical level, constructing cycle, equipment manufacturing, and localization, etc. shall be planned as a whole.

By the end of 2007, China’s PV accumulative installation capacity was 100MWp with PV installation capacity of 20MWp in 2007.

By the end of 2008, China’s PV accumulative installation capacity was 140MWp, with the current year PV installation capacity of 40MWp in 2008.

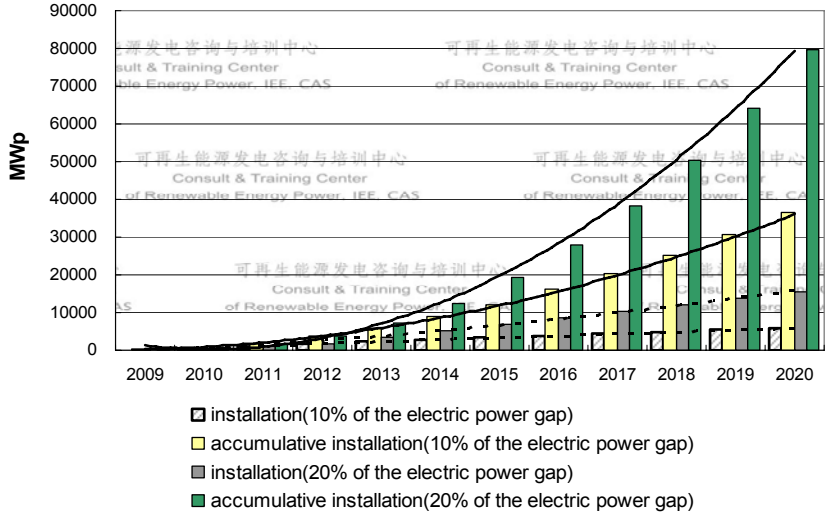

Fig 8-1 PV installation and accumulative installation scenario in 2009-2020

As shown in Fig 8-1, in 2010, PV accumulative installation will be 560MWp, accounting for 0.61‰ in the total power capacity installation. In terms of 10%-20% of the shortage of electric power, in 2015, PV accumulative installation will be 12GWp-19GWp, accounting for 0.86%-1.3%; in 2020, PV accumulative installation will be 37GWp-80GWp, accounting for 2.3%-4.7%.

In 2009-2012, the planned new installed PV capacity will be 3.5 GWp in the 4 years. With considering the subsequent development, after 2012, the annual increment will be 500MWp-1,700MWp based on the last year PV installation. The PV project progress scenario sees also Fig 8-1 and Tab 8-1.

By 2020, based on the accumulative PV power installation capacity of 140 MWp, by calculating the filling-up of electricity gap in 2020 with 10% and 20%, the newly increased PV power installation capacity will be 37 GWp and 80 GWp respectively,

Tab 8-1 PV project developing scenario Unit: MWp

2006 Installation	10	Accumulative quantity put into operation at the end of	2006	80
2007 Installation	20		2007	100
2008 Installation	40		2008	140
2009 Installation	**150**		2009	212
2010 Installation	**300**		2010	560
	The capacity being started during the years of, MWp	Accumulative quantity being put into operation during the years of, MWp	Quantity being carried forwarded to the next 5 years, MWp	Accumulative operating quantity at the end of the 5 years , MWp
2009-2010	690	490	200	560
2011-2015	11,430-18,630	10,290-15,850	1,340-2,508	10,850-16,410
2016-2020	24,250--60,250	26,480-61,552	2,340-5,908	37,332-77,372

In terms of models of operation and management of PV projects, the new construction , operation and management models will be set up, which link to the international advanced level, and the Chinese complete PV industry system will be formed; with regard to the project construction, the competitive system will be adopted as a whole, in order to lift up the managing level and decrease the engineering cost further; with respects of the economy of the PV project, by assuring the safety and the reliability of PV power plants, the operation cost shall be decreased further, by spending 5-7 years attains the goals that feed-in tariff of PV power will be competitive with that of the desulphurization coal fired thermal power, or reach the same level of tariff. With the rules and technology standards, facility management, engineering designing, manufacturing, and constructing, operation, etc. a set of rules, laws and standards system will be established, which will accord with the Chinese reality and link to the international.

8.4 Investment cost estimation

In accordance with a rough estimation of the total scale of the new projects and the projects being put into operation in 2009-2020, investment cost of the PV power projects is about RMB 658.1-1414.1 billion, of which the demand for the project equity capital is RMB 131.62-282.82 billion during 12 years (2009-2020), an annual average of its own capital of the enterprises is about RMB 10.97-23.57 billion (based that equity capital is 20% of the total investment cost).

Tab 8-2 Estimation of investment cost

	The capacity being started during the years of MW	Average unit MW investment cost, 10^4 RMB	Total, 10^8 RMB
2009-2010	690	2500	172.5
2011-2015	11,430-18,630	2000	2,286-3,726
2016-2020	24,250--60,250	1700	4,122.5-10,242.5
		Total	6,581-14,141

Tab 8-3 Tariff subsidy estimation

	The capacity being started during the years of MW	Power generation estimation 10^8 KWh	Average unit kW investment cost, 10^4 RMB	Tariff estimated RMB /kWh	At that time, the average conventional grid tariff, RMB /kWh	Tariff subsidy total 10^8 RMB
2009-2010	690	8.3	2.5	1.4	0.5	8.3
2011-2015	11,430-18,630	137.2-223.56	2.0	1.1	0.6	54.9-89.42
2016-2020	24,250--60,250	291-723	1.7	0.8	0.8	0

*：The estimation does not consider the fiscal subsidy on the investment side; all subsidies are looked as tariff subsidy, as estimating the subsidy amount.

8.5 Key tasks

1. Rural no-electricity electric power construction program

The stress is to solve the electric power supply in rural no-electricity area, and to improve the energy consuming conditions of residents in rural areas.

2. Urban distributed PV power pilot project

The stress is to develop the municipal PV pilot projects, with the rich resources potentials, and with the matured technologies, to drive the industrialized development by large scale building, including PV roof, BIPV/BAPV, street lamp, etc.

3. Open field grid-connected power pilot projects

8.6 Expecting benefit analysis

1. International impact

Energy is the vital physical condition of human survival and development. Coal, petroleum, natural gas and other resources have supported the development of human civilization and economic society at the 19-20th century for nearly 200 years. However with the continuous growth of consumption and large number of consumption of coal, petroleum, natural gas and other non-renewable energy, not only mankind is facing the risk and pressure of resource exhaustion, but also makes all the countries fell into the threat of serious living circumstances.

As we all know, the limitation, the non-renewable, and the serious impact on the environment of the fossil fuel resource results in the substantial emissions of greenhouse gases, global warming, regional climate and serious ecological deterioration, high frequency of natural disasters, etc., all of this have bring the tremendous pressure and fear to human existence.

In December 1997, 159 parties of UNFCCC signed the Kyoto Protocol. The Protocol has assigned specific emission reduction targets for greenhouse gases (GHG), including CO_2 and 5 other kinds of GHG, for 38 OECD countries or country groupings and countries under transition. In the first commitment period, 2008 to 2012, these parties should reduce the GHG emissions to 5.2% below the 1990 levels. Developing countries have no obligation to reduce emission. Chinese government signed the Kyoto Protocol on Mar 29, 1998.

At the Beijing 2005 Congress of World Renewable Energy, Chinese vice premier, Zeng Peiyan, announced that in 2020 China renewable energy will account for 15% of the total energy consumption.

As the first large developing country with the biggest energy consumption quantity, China launches the large scale solar power program, which not only provides the reference for the world to solve energy and environment issues, but also exert the leading effect in the world. Meanwhile it is one way of undertaking the obligation of emission reduction and fulfilling international commitment.

And the implementation of large scale solar power program in China can be viewed as an example, to show the Chinese activities of developing clean energy, reducing the greenhouse gas, removing poverty, and improving people’s livelihood to the world, which will raise the international influence.

2. Social benefit

As Chinese PV industry develops into an important part of electrical power

energy, the significant social benefits will be as follows:

Employment will be increased. The development of PV industries can be beneficial to increase employment and stabilize the society. Currently, the total employment of the Chinese PV industry is nearly 100,000 and an average of 50 persons per MWp. If solar cell development goals of annual output of 6GWp can be attained by 2010, the PV industry can provide 300,000 jobs. If Solar cell production will be 12GWp-30GWp by 2020, employment will be increased by 0.6-1.5 million in 2020.

Non-electricity population will be reduced. Through the large-scale PV power program, the power supply problems in no-electricity villages and households will be solved. Large-scale PV power can make the 10 million no-electricity rural residents out of the laggard life of no touch with reality and use of firewood and candlelight, where the grid can not be accessed to. The population can enjoy the modernized civilization - electric power and TV can make the people have the chances to know the external information, the society, and the laggard concept will be changed with the electrification, and the poverty will be alleviated.

Large-scale PV power program will draw the relevant industries such as glass making, Si material technology improvement, construction, machinery processing, and the transportation. Correspondingly, the service industries, such as the rural power service, will be developed very quickly.

Energy safety and the energy structure will be improved greatly. Solar resource is unlimited and is not confined by the external conditions. As PV power become the main component of Chinese energy supply, the situation of Chinese energy and electric power structure will be improved a lot accordingly.

Large-scale PV power program will save and substitute a great deal of fossil fuel, which will reduce the pollutants and greenhouse gas evidently, promote the harmonious development between human beings and nature. it will play important roles on the building of the socialism new villages and the well-to-do society, and will powerfully promote the sustainable development of economy and prosperous society.

3. Environmental benefit

No matter from the point of view of energy or that of the environmental, PV power generation is a clean energy and renewable energy, and is also the emphasis of development in recent years. Large-scale application of PV power generation will undoubtedly bring about excellent environmental benefits.

By 2010, Chinese PV accumulative installation will be 560MWp. Based on the annual full operation hours as 1,200 hours, the annual power generation will be 672 GWh, which saves 2.55×10^5 tons coal correspondingly, the annual emission reduction of CO_2 will be 6.72×10^5 tons, reduced ash slag will be 2,550 tons, fly ash will be 510 tons, SO_2 will be 4,590 tons, and NOx will be 1,137 tons.

By 2020, Chinese PV accumulative installation will be 37-80 GWp, the power generation will be 43.644-94.365 TWh, the annual emission reduction of CO_2 will be 44-96 million tons, ash slag of burned coal will be 1.658×10^5-3.585×10^5 tons, fly ash will be 3.32×10^4-7.18×10^4 tons, SO_2 will be 3×10^5-6.486×10^5 tons, NOx will be 7.4×10^4-16×10^4 tons.

4. Economic benefit

In China, developing PV industry and market powerfully will not only brings about the vast social and environmental benefits, but also formulates an new important component in new and renewbale energy economy and a new point of economy growth, and promotes creating a new mode of economy, and makes contribution to the sustainable development of economy.

By roughly estimating the total operating PV power capacity, average unit MW investment cost, power generation quantity, and the tariff estimated during each period of 5-year (Tab 8-1,8-2 and 8-3), the economic benefits of PV power industry in 2009-2020 can be gained (based on the taxation rate at 25%). Expected in 2020, the taxes amount created by PV industry will be RMB 164-345 billion, as shown in Tab 8-4.

Tab 8-4 Tax & profits created by PV industry

	Profit and tax in fixed asset investment, RMB $\times10^8$ Yuan	Profit and Tax in the sales of power generation $\times10^8$ Yuan	Total $\times10^8$ Yuan
2009-2010	35	3.11	38.11
2011-2015	542.5-820.5	34.34-55.89	88.84-876.39
2015-2020	1,586.61-3,312.11	54.56-135.56	1,641.17-3,447.67

8.7 summary

1. Developing targets

   1) By 2009-2012, the planned newly installed PV power capacity will be 120 MWp, 500 MWp, 1,030 MWp and 1,850 MWp each year respectively.

   2) After 2012, there will be an increment amount of 500 MWp thru 1,700MWp each year, based on the last year PV power installation capacity. The total installed PV power capacity in 2011-2015 will be

11.43GWp-18.63GWp. At the end of 2015, Chinese PV accumulative installation will be 10.85GWp-16.41GWp.

3) In 2016-2020, total installed PV power capacity quantity in the 5 years will be 24.25GWp-60.25GWp. At the end of 2020, Chinese PV accumulative installation will be 37GWp-80GWp.

2. The scale of investment

1) With regard to the average investment cost of unit kW in three phases:

In 2009-2010, the investment cost will be RMB 25,000 /kWp and the total investment will be RMB 17.25 billion.

In 2011-2015, the investment cost estimated will be 20,000 RMB/kWp and the total investment will be RMB 228.6-372.6 billion.

In 2016-2020, the investment cost estimated will be RMB17,000 /kWp and the total investment is RMB 412.25-1,024.25 billion.

The total investment needed during 2009-2020 will be estimated as RMB 658.1- 1,414.1 billion, of which the project demands for the equity capital during 12 years (2009-2020) will be RMB 131.62-282.82 billion (based of 20% of the total investment amount).

2) The per kWh cost can also be considered in three phases:

In 2009-2010, the average conventional grid tariff will be RMB0.5 Yuan/ KWh, and the average PV power tariff estimated will be RMB1.4 Yuan/KWh.

In 2011-2015, the average conventional grid tariff will be RMB0.6 Yuan/ KWh, and the average PV power tariff RMB1.1 Yuan/KWh.

In 2016-2020, the average conventional grid tariff will be equal to the average PV power tariff with about RMB0.8 Yuan/KWh, and renewable energy power tariff subsidy will not be necessary.

The total cross subsidy will be RMB 6.32-9.772 billion in 2009-2015.

3. Profit analysis

1) As the first largest developing country with the biggest energy consumption, large scale solar power program in China not only provides the reference for the world to solve the energy and environment issues, but also exert the leading effect in the world. Meanwhile it is one way of undertaking the obligation of emission reduction and fulfilling international commitment. And Chinese action of solar power program can be looked as an example: to show the Chinese activities of

developing clean energy, reducing the greenhouse gas, removing poverty, and improving people’s livelihood, raises the Chinese impact in the world.

2) Large-scale developing of solar PV power has the significant social benefits. First, it is beneficial to increase employment and stablize the society. Second, it reduces non-electricity populations and improves people's livelihood, and can promote the physical and spiritual civilization and the progress. Third, it can economize the natural resources, improve the environment, alleviate the reliance on fossil fuels and reduce the greenhouse gas emissions. Fourth, it will draw the relevant industries. Fifth, it can optimize the energy structure and make contribution to the electric power sustainable development in the future.

3) Environmental benefit: large-scale application of PV grid-connected power will undoubtedly bring good environmental benefits.

4) Economic benefit: It can become an new economic growth point, and to make contribution to the sustainable development of economic.

Reference

[1] NEA，*2009-2011 Energy Prosperity Plan*，2009.2

[2] NDRC, *Energy Development 11th 5-year Plan*, April, 2007

[3] China Renewable Energy Promotion Law

[4] NDRC, *Renewable Energy Medium and Long-Term Development Plan*, (NDRC Energy [2007] No. 2174), on Aug 31, 2007

[5] NDRC, *Renewable Energy Development 11th 5-year Plan*, (NDRC Energy [2008] No. 610), on Mar 3, 2008

[6] Institute of Electrical Engineering, Chinese Academy of Sciences, *China’s PV Development 11th 5-year Plan* (proposed draft), 2005

[7] Zhao Yuwen, Wang Sicheng, et al., R*eport on the Development of the Photovoltaic Industry in China (2006-2007)*, NDRC/WB/GEF/REDP, May,2008

[8] Li Junfeng, Wang Sicheng, et al, *China Solar PV Development Research Report (2007)*, Sep, 2007

[9] Wang Sicheng, *Estimate of Tariff of Solar PV Power Generation*, prepared for NDRC

[10] Wang Sicheng, *Latest Progress on China Solar PV Power Generation*, 5th Workshop on Chinese Solar Grade Silicon and PV Power, March 17,2009

[11] Institute of Electrical Engineering, Chinese Academy of Sciences, *Design and Consultancy of renewable energy rural electrification, 2nd report: Options and the recommendation of SDDC*, funded by NDRC/WB/ GEF/REDP.

9. Conclusion and Proposals of Policies

9.1 Conclusion

1. Necessity

1) Fossil energy resources are limited and non-renewable.

2) China's energy situation is much more austere than the world, and the situation of renewable and alternative energy in China is much more urgent and severe than the world. At present the quantity of Chinese energy-consumption is big number and rises faster, so the depletion process of conventional energy sources is sped up.

3) China's energy structure is irrational and the renewable clean energy needs to be developed. China has the abundant solar energy resources. It has offered the favorable term for the development of solar PV power generation. It also can provide the favorable conditions for overall improvement of energy structure and sustainable development of energy from a long-term and strategic point of view.

4) There will be considerable electricity shortages in China in 2020-2050 even allowing for rapid economic development and resources in China. It is therefore imperative to increase the rate of development of PV energy generation to cover the shortfall in electricity supply while optimizing energy structure, improving the environment and realizing sustainable energy production.

5) At present China is facing the dual international pressure of energy and environment. The main energy source in China is coal accounting for more than two-thirds of total energy supply. China is the country with the most severe SO_2 emission and the most badly acid rain pollution in the world, due to coal misuse. Besides coal-fired power generation, direct coal firing is in many applications, which emit much more severe pollutants. Pollutants from coal combustion are the major source of Chinese air pollution. In 2007, China was the world first SO_2 emission country continually, China CO_2 emission became the world first one, over the United States (in 2007, USA CO2 emission was 5.91 billion tons, and China is 6.02 billion tons). This brings China great pressure in energy saving, emission reduction, energy structure improvement, and the sustainable development.

2. Strategic significance

1) As the first large developing country with the biggest energy consumption, China launches the large scale solar power program, which not only provide the references for the world to address the issues of the energy and environment, but also exert the leading impact in the world, meanwhile it is the way of undertaking

the obligation of emission reduction and fulfilling international commitment. And Chinese action of solar power program can be looked as an example, to show the Chinese actions and attitudes for developing clean energy, reducing the greenhouse gas, removing poverty, and improving people's livelihood to the world, which will greatly boost the Chinese impact.

2) It is of significance in terms of social, and economic, and practical benefit to powerfully develop the large-scale Chinese PV industry and market. Firstly, be beneficial to the employment increasing and the society stabilization; secondly, to reduce the no-electricity population and improve people's livelihood, and promote the physical and spiritual civilization progress; thirdly, to save the natural resources, improve the environment, reduce dependence on fossil fuels and reduce the greenhouse gas emissions; fourthly, to drive the relevant industries development; fifthly, to optimize the energy structure and electric power sustainable development in the future.

3) Developing large scale PV power can contribute to the eco- environment protection of the globe. China's environmental situation is serious, with 2/3 of the lands being under the threat of acid precipitation and acid rain and the overall environmental quality levels continue to deteriorate. China has accounted for the majority of the world's top 10 polluted cities. Environmental pollution has seriously affected to economic development and social progress and people's health.

4) Solution to the problem of power supply in no-electricity areas. Solar PV system is very suitable for installation in remote rural areas, where is unable to access the power grid for many years. PV power is particularly suitable for decentralized communities far from the grid. Off-grid system can set up a home or small power grid. PV power or other renewable powers can be in combination with LPG/diesel to provide electrical energy for lighting, refrigeration, education, communication and health;, PV power can increase income and create more opportunities to increase income. PV power system has the characteristic of durableness and robusticity, simplicity and flexibility of installation, so that it can meet rural demand of electricity in the world.

5) To develop PV power generation on a large-scale can greatly optimize structure of electrical power, and it also can supply green power to grid.

6) To solve the situation of power supply and demand imbalance in the future, renewable energy power is a good way to supplement the shortage of electricity. Solar energy will be the main source of energy in the future in China.

7) PV power has its unique irreplaceable superiority. It will play an important role in the energy structure of electric power in the future. However; only solar energy can assure to meet the demand of the human future energy, with its potential

resource capacity of 120,000TW, the actual utilizable fraction as high as 600TW. Solar PV power will be the renewable energy power technology with the most potential, it will play very important role in the future energy and resource..

8) Developing solar power will reduce the dependence on fossil energy, and contribute to national energy supply security..

3. Feasibility

1) From the solar energy resources, China has the advantageous solar energy resources conditions. More than two thirds of the national land areas can install PV power system. Obviously, solar power has great potentials for applications and broad market potentials in China.

2) From the view of policies, laws and regulations, the NDRC, NEA and SERC have issued the related policies to stipulate many measures for the implementation of solar PV power generation projects (grid-connected systems and off-grid systems). With regard to the specific issues for different provinces (autonomous regions) and different systematic approachs of PV power, the policies shall be further detailed, so as to make maneuverable and viable. The European, U.S.A and other countries, can be learned as the references; the related policies can be implemented and improved through pilot and demonstration projects.

3) From the point of PV technology in China, manufacture of crystal silicon solar cell is a mature technology, and Chinese solar cell production capacity accounts for nearly 70% of the global. These technologies of grid-connected PV power generation, off-grid PV power generation, BIPV/BAPV and PV lamps are being matured. However, ever since for the high cost of always PV power, crystalline silicon solar cells can not compete with conventional thermal power generation in the short term.

4) Currently, the thin film solar cell technology has developed rapidly due to advantages of costs and technology, but the efficiency and reliability are needed to improve. The market share of thin film solar cells continues to rise for the increase of market demand.

5) In the long run, whether crystalline silicon solar cells or the thin film solar cells, the cost of PV power will be reduced for the technological advances and increase in market size.

6) From experiences and lessons from the off-grid PV power project, the ownership of PV power projects must be firstly set up; secondly, the PV power projects' operation, maintenance, and management issues must be resolved and clarified; thirdly, the whole process of project quality control shall be emphasized.

7) The market development depends on costs & benefits, market demand, product

quality, service and so on. The development and exploitation of PV market should be in accordance with the rules of market economy. Government plays the roles of supervision, guidance and macro-control.

8) China already possesses the basic conditions for large-scale PV power applications as follows: broad prospects, huge potential of market, fundamental maturity of the policies and the circumstance, proven equipments and technology, and non-reliance on imports. By establishing the feasible development targets of market and implementation steps, and stimulating the development of domestic PV markets, the promotion and upgrading of PV industry technology and the competition mechanisms, Chinese PV power will be competitive with conventional thermal power generation.

4. Key Conclusions

1) From long-term strategic point of view, whoever holding the commanding height of PV power will grasp the future energy and development initiative. On the one hand, Chinese PV industry should be promoted by the great international photovoltaic market demands; on the other hand, PV industry should promote the development of domestic market and carefully nurture the domestic market to continue stepping into the international market as well.

2) The present developing situation: The PV industry was hard hit by the global financial crisis. After 5 years of rapid development, Chinese PV industry is facing the inevitable stage of re-configuration. With the outbreak of the global financial crisis and explosion of the poly-crystalline Si production capacity, a new modulation of Chinese PV industry is getting urgent and closer. Whoever owns the superiority of capital and technical strengths to survive through the crisis will be able to get the next round of explosive growth.

3) Analysis of poly-crystalline silicon industry chain, the trend of cost and price

(1) Characteristics of present PV industry chain in China: 1) **Chinese PV industry chain is becoming integrated**. The situation of the small crystalline silicon capacity and the large production of c-Si PV module have been changed. The nowadays situation is that, because of crystalline silicon fabrication technology breakthrough, ingot/wafer and solar cell manufacturing developed rapidly, many new PV module enterprises are emerging; 2) **PV industry of China developed dramatically**. The highest annual growth rate is 300% from 2002 thru 2008; the production output of PV module tops the first in the world in 2007 and 2008. 3) **Large investment is on PV industry**. The planned capacity of poly-crystalline silicon is over 100,000 tons and its investment more than RMB 100 billion. The formed capacity of ingot/wafer, cell and module capacity is totally 5,000 MWp/yr, with

RMB 50 billion on fixed assets investment, the in construction capacity of ingot/wafer, cell and module capacity is 3,000 MWp/yr totally, with RMB 30 billion investment. 4) **Some problems exist in Chinese PV industry**. PV module highly relies on foreign consumption, the uneven geographical distribution of PV industry. 5) With the outbreak of the global financial crisis, global demand of PV decreases; Chinese PV industry is facing risks, but also having the opportunity for developing.

(2) Status of Chinese PV industry: 1) The purification technology of poly-crystalline Si made breakthrough. The lowest energy consumption of manufacturing poly-crystalline Si is 127kWh/kg, which closes to the top level of the world. Over 10 companies begin to produce poly-C Si, and the production output is about 4,500 tons in 2008; 2) the manufacturing technology of ingot/wafer has reached the international advanced level, the energy consumption of advanced enterprises is only 62 kWh/ kg, and the main production equipment can be made in China by Chinese companies. Total ingot/wafer production output is 20,000 tons in 2008; 3) the manufacturing technology of solar cell is advanced. The technology of the first class companies keep pace with the international, the energy consumption is about 220kWh/kWp. The solar cell production is over 2GWp in 2008; 4) the encapsulation technology of PV module is mature; the main production equipments can be made by local companies. Production capacity of PV module is about 5000WMp/yr, and more than 330 enterprises are engaged in PV module encapsulation.

(3) The status of cost and price of PV production: In 2008 the average global price of crystalline silicon PV modules has risen to USD 4.26 /Wp, higher than that in 2007. With the outbreak of financial crisis, the price of PV modules has dropped sharply to USD 2.8/Wp. The price of PV modules in China is basically the same with the international, but the composition proportion of the cost of PV modules is different. The poly-crystalline silicon material csot accounts for 41% of the total cost of PV module in domestic companies, while that is 29% in the cost of the foreign PV module. Domestic PV module product has the feature of higher poly-crystalline Si material cost, lower labor cost, and etc.

(4) **Technology potential and cost trend of PV in China:** The cost and the price of c-Si PV modules decline is an inevitable trend. On the one hand, the Chinese manufacturing technology of c-Si solar cell have made tremendous progress. The main expression is that the purification technology of poly-crystalline Si has made a breakthrough, the thickness of wafer continues to be thinned, and the efficiency of cell was improved continuously

and so on. On the other hand, the price of poly-crystalline Si is becoming rational, the spot price of poly-crystalline Si dropped by 70 percent to the high price in 2008. This will greatly reduce the cost of PV module.

(5) Estimation of **cost and tariff of PV power system:** Along with technological progress, improvement of PV efficiency, life extension, and economics of scale, the cost of PV power will decline gradually. On the basis of initial investment of RMB27, 500/kWp, annual effective hours of 1800, the feed-in tariff of PV power is about RMB 1.68/kWh. If the initial investment of RMB27500/kWp with the annual reduction of 10%/yr, annual effective hours of 1800, the cost of traditional electricity is 0.59/kWh with annual growth rate of 5%/yr, the PV power can be equalized to the tariff of coal fired power in 2016, around RMB 0.80/kWh.

4) Energy recovery cycle of PV power: Without considering the energy consumption of PV system installation, operation and equipment recycle, the overall energy consumption of PV system in life is the sum of producing and manufacturing energy consumption of 3,080kWh/kWp and the energy consumption of consumable materials of 737kWh/kWp; total energy consumption in PV system life is 3,817kWh/kWp. Energy recovery cycle of PV power system will reduced to 1~2 years in future.

5) Issue of pollution control in PV industry chain. CO_2 emission in the ironing process from quartz sand to metallurgical grade silicon is the biggest pollution source, it shall be controlled. $SICl_4$, by-product of the poly-crystalline Si purification will be in great dangers, without proper treatment and recovery. The zero-emission and the full clean production can be realized, no technical barrier exists, if the poly-crystalline Si factory adopts the tail gas recovery, material circulating, and the integrated utilization. With regard to the ingot/wafer and the cell producing process, the complete process is adopted, it is the process used commonly in the silicon mono-crystalline fabrication of the micro- electronic industry, no problem of pollution exist if only being treated properly. In PV module encapsulation, almost no waste liquid and gas emit, no other pollutants emit.

6) The off-grid PV power application is a very big market, if in the non-electrified area, the off-grid PV power system is used to supply the power for the no electricity residents in remote area with yearly per capita of 200 kWh, the total capacity of off-grid PV power needed is about 2.5GWp, If the Chinese 850, 000 square kilometers deserted area is covered by the large scale PV power plants, as the strategic developing bases, and based on the 50MWp PV panel per square kilometer, the total potential capacity of large scale PV power will be up to at least 1500 GWp.

7) Safety issue of PV grid-connected power. The technological requirement for the PV grid-connected power has been presented. The electricity quality requirements of grid-connected power can refer to the national standard GB/T20046-2006, named as P*hotovoltaic (PV) System characteristics of the Utility Interface*. This standard mainly adopts articles of IEC61727:2004. Electricity from PV system is more stable than that of wind power regarding to power output. At the same time, the power of single PV equipment is lower than that of wind power, so that as PV equipment failure happens, the impact on the utility grid is small. However, in term of the Chinese weak grid, certain amount of research needs to be done in order to prevent problems from appearing as large scale PV power system connect to the weak utility grid in the future. Generally, PV system connected to single medium voltage line is prone to control and greatly reduce the effect due to partial failure.

8) Major factors impeding Chinese PV market development: ⑴ solar PV power has not been elevated to the strategic height; ⑵ The development planning targets of Chinese PV power is too low; ⑶ Although the related incentive policies for PV developments have been enacted, but the policies is lack of maneuverability, such as there is no the public and definite tariff of grid-connected PV power . ⑷ The motivating strength of incentive policies was not enough. ⑸ The cost of PV power is higher than conventional power generation. ⑹ PV industry chain are less competitive totally. ⑺ Domestic poly-crystalline silicon purification technology is backward, the price rises non-rationally. ⑻ The demands of domestic PV market are insufficient. ⑼ Lack of PV professional talents. ⑽ PV grid-connected technology large scale experiments have not been carried out yet. ⑾ Relevant technological standards and criteria are not complete and not comprehensive.

9) **Near term targets**

"PV Upspringing Plan 2009" yearly investment and installation capacity

Year	2009	2010	2011	2012	total
Current year installation capacity（MWp)	120	500	1,030	1,850	3,500
Yearly investment (RMB 100 million)	29.0	111.0	204.0	322.5	666.45
Accumulative new installation capacity（MWp)	120	620	1,650	3,500	
Accumulative new investment (RMB 100 million)	29.0	140	343.95	666.45	

In 2009-2012, the planned PV projects by type and the capacity are as follows,

(1) Non-electrified area electrical power development program. PV installation

capacity will be 20MWp in 2009 and 370MWp totally in 2009-2012.

(2) Open field grid-connected PV power plant program. PV installation capacity will be 60MWp in 2009 and 1,910 MWp totally in 2009-2012.

(3) City emergency response power supply sources program. The emergency shelter and the institutions' PV installation capacity will be 15MWp in 2009 and 365 MWp totally in 2009-2012.

(4) Urban grid-connected PV power. PV installation capacity will be 20MWp in 2009 and 7,500 MWp totally during 2009-2012.

(5) PV lighting program. The 100,000 PV lamps will be installed with total capacity of 5MWp in 2009 and 105MWp totally during 2009-2012. Total installed PV lamps will be 2 million named as "2 million PV lamps" project.

10) Fund sources and the financing mode: 1) Project partial investment, government subsidies, commercial operation, no tariff subsidies, 2) full commercial mode, with tariff subsidies, 2) Governmental full grant.

11) Long term targets

(1) After 2012, there will be an increment amount of 500 MWp thru 1,700MWp each year, based on the last year PV power installation capacity. The total installed PV power capacity in 2011-2015 will be 11.43GWp-18.63GWp. At the end of 2015, Chinese PV accumulative installation will be 10.85GWp-16.41GWp.

(2) In 2016-2020, total installed PV power capacity quantity in the 5 years will be 24.25GWp-60.25GWp. At the end of 2020, Chinese PV accumulative installation will be 37GWp-80GWp.

12) The scale of investment

(1) With regard to the average investment cost of unit kW in three phases:

In 2009-2010, the investment cost will be RMB 25,000 /kWp and the total investment will be RMB 17.25 billion.

In 2011-2015, the investment cost estimated will be 20,000 RMB/kWp and the total investment will be RMB 228.6-372.6 billion.

In 2016-2020, the investment cost estimated will be RMB17,000 /kWp and the total investment is RMB 412.25-1,024.25 billion.

The total investment needed during 2009-2020 will be estimated as RMB 658.1-1,414.1 billion, of which the project demands for the equity capital during 12 years (2009-2020) will be RMB 131.62-282.82 billion (based of 20% of the total investment amount).

(2) The per kWh cost can also be considered in three phases:

In 2009-2010, the average conventional grid tariff will be RMB0.5 Yuan/KWh, and the average PV power tariff estimated will be RMB1.4 Yuan/KWh.

In 2011-2015, the average conventional grid tariff will be RMB0.6 Yuan/KWh, and the average PV power tariff RMB1.1 Yuan/KWh.

In 2016-2020, the average conventional grid tariff will be equal to the average PV power tariff with about RMB0.8 Yuan/KWh, and renewable energy power tariff subsidy will not be necessary.

The total cross subsidy will be RMB 6.32-9.772 billion in 2009-2015.

13) Key tasks: (1) Rural no-electricity electric power construction program: (2) Urban distributed PV power pilot project: (3) Open field grid-connected power pilot project

14) Recommended that: the major projects, which can be subsidized by the Government, include the non-electrified area power development projects, emergency power supply sources program, and PV lighting projects; and it is proposed that non-electrified area power development projects shall have no less than 50% central finance, emergency PV power sources and PV lighting project shall be mainly funded by local funds and central government subsidize about 20%.

15) Recommended that the installation capacity of grid-connected PV station projects in the open fields be 1,910MWp in 2009-2012. The State shall carry out the feasibility study on the construction of large-scale renewable energy power generation base in the deserted areas where are rich in resources and close to power transmission line such as in Inner Mongolia and in Hebei soon. The attention shall be paid to the large-scale poly energy hybrid systems of PV power, other renewable energy power, and energy storage system, such as wind power, solar thermal power, biomass power, pumped storage power, gas turbine, etc. Such integrated energy system can be stable in output, dispatchable, predictable and reasonable in electric power transmission. As the program is approved, the large-scale construction shall be implemented as soon as possible, as the experience is learned from the pilot, the program shall be scaled up and spread over. Grid-connected PV power projects in the open fields shall adopt he mechanism of subsidy-sharing on grid.

16) Recommended that emergency response systems and shelter PV power supply sources and solar PV power street lamps project are funded mainly by local governmental funds and the central government subsidize 20%.

17) Recommended that 1) the operational and management of off-grid PV power

station in no-electricity areas, SHS systems and emergency power sources charged by the local grid Corp, by following the current mechanism of subsidy and whole grid-sharing. 2) Bidding for grid-connected PV station projects in the open fields shall examined and approved by the local Development and Reform Commission (DRC) and reported to the State NEA for verification. 3) Urban distributed grid-connected PV systems, below a certain power (decided by power sector) adopt mechanism of investment side subsidy. The mechanism of meter-offsetting is adopted so as to benefit the investor and award the green certificate as a social honor.

9.2 Policies and Measurements Proposals

1. Making the laws and rules further complete

Further improvement shall be made on the laws system mainly based on the principle of "*Chinese Renewable Energy Promotion Law*". By implementing the regulations stipulated by NDRC, NEA, and State Electric Regulatory Commission (SERC), the industry policies and rules shall be made detailed correspondingly. It is recommended that the Government Departments shall draw up the portfolio system of renewable power for the State Electric Power Groups, Power Supply Administrations, and the provincial utilities as soon as possible, including the proportion of the solar PV power generation.

2. Strengthening the planning and macro- control

The PV power strategic position shall be stressed, the functions of PV industry development planning, and the large PV power project construction plans shall be strengthened, the developing order needs to be regularized, the construction project management shall be enforced, the industry development layout and the constructing scale shall be adjusted and controlled as necessary. In order to avoid the surplus of the energy production, the developing plan can be tuned accordingly.

The system of plan making, improving, and adjusting, releasing, and publicizing of PV project plan shall be established and improved; the progress of the plan implementation shall be publicized to the public. The relative plans made by local governments and administrations shall accord with the national PV development plan, and should be included into national one.

The system of the construction project approval and the system of being-put-into -record are seriously carried out. The management system and method shall be formed more scientifically, normatively, and transparently, by using the complete project approval and system of putting-into-record. With the PV projects which does not comply with the national industry plan and policies, it is not allowed to proceed the relative checking and permitting, financing agencies and banks will not be allowed to supply loan for the project.

3. Promoting the system innovation

According to the State general requirement, the modern enterprise system and property right system shall be built completely, and the mechanism and the system shall be innovated gradually. The market competition system shall be used in the PV power plant construction and the O/M after the completion of the PV power plant. Other issues, such as sciences and technologies research, designing, manufacturing, constructing, and operating, shall be guided by the market competition mechanism.

4. Building the persistent and stable PV power market demand

The state shall adopt the comprehensive measures of financing, taxation, and pricing, and compulsory policies of market shares. The relevant administration shall foster the stable and persisting electric power market of PV power, by the means of organizing the governmental investment project, the concession project, and so on, The PV electric power market shall follow the principles of government-guiding, policies-supporting, and market-pushing, based on the regulated developing targets.

In accordance with the strategic development plan, the national responsible administrations shall make the PV near- and medium-term development plans, make the policies and the funds put into effect, determine the layout of the installation and industry of the provinces involved, and guide the sustainable, rapid and healthy development of the PV market and industry. It is recommended that a series of the pilot projects shall be started up, such as "Non-electrified Area Electric Power Building Program", "Large-scale Desert grid-connected PV Power Program", "Emergency PV Power Sources for Emergency Response System", and " Large-scale Integrated PV Urban Applications" in the provinces and the regions where have the better conditions and the local government actively involved in; the practical mechanism of projects operation, related policies and standards system shall be made; as the experiences is learned, it shall be generalized cross the county. Recommend that the project of "Large-scale Desert Grid-Connected PV Power System" adopts mechanism of subsidies of feed-in tariff, and the other projects adopt mechanism of investment side subsidy or mechanism of investments plus tariff subsidy. The State Council responsible administration shall be in charge of organizing and establishing the grid-connected PV operation regulation. In order to make the best use of the renewable energy, the electricity dispatching institution shall arrange the electricity generation and the dispatching work, according to the “*Renewable Energy Promotion Law*”; the Grid Corp. shall be responsible for the construction plan of the electricity dispatching engineering and arrange the construction plan of electricity transmission channel in advance and make effort in grid-connecting layout and the experimental research; the Grid Corp. ensures fully the PV power feeding-in-grid and electricity purchase, and guarantees the implementing of the subsidization policies, according to

the electric power layout in the development plan.

The responsible construction administration of the State Council and national standard commission organize to make the BIPV standards, consummate the relative construction standards, engineering criterion, and the municipal constructing management regulations to create the conditions for the applications of PV in buildings.

Ministry of Finance and Ministry of Housing and Urban-Rural of the Development of the People's Republic of China have issued the policy of BIPV investment side subsidy to promote the political mechanism of BIPV/BAPV. It is recommended that the government coordinate the Power Supply Departments to draw up a reasonable standard of feed-in tariff. First of all, it shall be allowed to achieve the table clearance system and make breakthrough in the barriers of grid-connected BIPV/BAPV. Under the necessary policies, it is necessary to expand compulsorily the market share of solar PV generation technology in the towns and cities where solar energy resources is rich and with the better economic conditions.

The above projects should be preferential to the west and the regions where solar energy resource is rich and near the electric power load center. In order to solve the conflicts for paying much more electricity fees but with insufficient subsidies of RE power in the eastern provinces and municipalities, it is suggested that the state shall encourage the eastern enterprises and individuals to invest on PV projects in the western area and enjoy the preferential policies of local subsidy in west China.

To simplify the checking and approval procedure, it is suggested that the system shall be implemented, in which the provincial DRC checks and approves the project in accordance with the national plan, and the NEA verifies the project submitted by provincial DRC.

5. Consummating the tariff and the apportioning policies constituted already

The pricing responsible administration of State Council shall make and improve the feed-in tariff of PV power project by referring the technical characteristics of renewable energy power and situations in different areas, and by following the favorable principles for PV development, and by the principles of economy and rationality. The feed-in tariff of PV power shall be adjusted in time as necessary; the feed-in tariff of PV power project is performed according to the tariff by public bidding, and will be modified reasonably according to the market situations.

The grid enterprises purchase the electricity of renewable energy power generation, the excessive part of purchasing the electricity of renewable energy power, with above the conventional power tariff, shall be shared by the society in the RE tariff add-in.

6. Increasing the taxation and fiscal support strength

The state shall increase the finical input on PV project with increasing the fiscal budget capital and national debt; the investment strength shall be increased on the non-electrified area electric power construction. The political investment and the interest-discounted capital shall be arranged. With the construction of the Emergency Response System, funding for the use of PV power supply shall come from special funds for the construction of National Emergency Response System.

By following the portfolio system of renewable energy power of State Council, the renewable energy power tariff policies shall be improved in a great deal, and the taxation policies in favor of renewable energy power generation and consuming shall be executed, and the taxation preferentiality strength can be increased as well.

7. Implementing the incentive policies of financing, with strong maneuverability and practicability

To simplify the application procedures for the PV power project, and to decrease the proportion of equity capital in PV power project investment. The financing channel can be extended through issuing stock, bond, and so on, and scale of investment can be enlarged, in order to promote the diversification of the PV project financing.

8. Building the operation and technology service system.

According to the guidance of socialization, marketization, and specialization, with focusing on the PV power project development, design, constructing, commission, and operation, reparation, and personnel training, etc. corresponding scientific researches and affiliated equipments shall be implemented, and the complete PV power specialization operation and technology service systems shall be established, the PV power operation level shall be lifted up as a whole to create the favorable condition for more investors to invest the PV power project.

In order to provide the electric power service to rural residents and public facilities, and to assure the rural off-grid system to operate normally, it is encouraged for enterprises to set up the renewable energy service company in rural area.

9. Intensifying the science and technology research for technology breakthrough

In order to support the basic research of PV power technology, the state responsible administrations shall arrange the special program on science and technology breakthrough-making to support the common technologies and key technologies. The cooperation between enterprises and the research institutions is encouraged and the technologies innovation is favorable as well.

10. Stressing the education of the talents

In order to achieve the 2020 PV developing targets ahead of time, it is obligatory

for the state, enterprises, the educational institutions, and the research institutions to take the chance, to educate great amount of various capable personnel powerfully in the field of scientific research, designing, manufacturing, operating, maintenance, and management. For the professional personnel storage in the future, the salary and deal of the personnel shall be increased as necessary.

11. Strengthening the management of PV industry

To stress the management of full process of PV power project, and to fulfill the tasks of O&M of off-grid PV power system.

To lift up the entry threshold of PV industry, to standardize the producing and management of PV project , to guide the PV enterprise to increase the internal input and to make the technical innovation, and to lift the accoutrement level, shall be done. It is important to make the PV power electric market supervision and operation rules more improved, and to create the market circumstance of equal competition.

It is necessary to guide the PV power enterprises to emphasize the internal management, to make effort in decreasing the cost, to modify the service, and to provide the reliable electric power supply service, with the reasonable price and quality.

12. Improving the standard system

Speed-up modifying and revising the PV product and technologies standard and gradually improve and accelerate the standard system to integrated with the international one.

13. Strengthening international cooperation

With taking the aims of introducing advanced technologies, excellent talented people, and the management models, the international cooperation policies of PV project shall be improved, in terms of the principles of equality, mutual benefit, and double winning.

Reference

[1] NEA, ”*2009-2011 State Energy Prosperity Plan*”, Feb, 2009

[2] NDRC, *”Energy Development 11th Five-Year Plan”*, April, 2007

[3] NDRC, *Notice on the utilization policies of natural gas*, [2007] No. 2155, Aug 30, 2007

[4] China’s *Renewable Energy Promotion Law*

[5] NDRC, *"Medium and Long-Term Development Plan for Renewable Energy in China"*, NDRC Energy [2007] No. 2174, Aug 31, 2007

[6] NDRC, "*Renewable Energy Development 11th Five-Year Plan*", NDRC Energy [2008] No. 610, Mar 3, 2008,

[7] NDRC, "*Coal Industry Development 11th Five-Year Plan* ", Jan, 2007

[8] NDRC, "*Medium and Long-Term Development Plan for Nuclear Power (2005-2020)*", Dec, 2007

10. Appendices

10.1 Si-based thin film (A-Si (mono-, bi-, tri-junctions) a/u Crystalline) enterprises list

10.2 CdTe enterprises list

10.3 CIGS/CIS enterprises list

10.4 *Guideline on the Emergence PV Power Supply Source Project for Emergent Public Affairs Response and Tackling System* (proposed draft)

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