2007 CHINA SOLAR PV REPORT
中国光伏发展报告

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China Solar PV Report · 2007

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Preface

As a renewable and clean energy source, solar power has great development potential. Almost all the natural resources that human society makes use of are based on solar energy. Its use can be traced back to the origins of mankind. Solar power is the most basic energy for the survival of the human race and development of its technology to produce useful electricity is likely to determine the future life patterns of our planet.

Solar photovoltaic (PV) technology first emerged in the 1950s. It has been booming in recent years as a result of the global energy crisis. It is now widely used in countries such as Germany and Japan. Driven by the international market and domestic policy, China's solar PV industry has also witnessed fast development. A number of leading companies, such as Suntech, Trinasolar and Tianwei Yingli, are expanding, and driving the development of related companies in the solar PV industry chain.

Although currently the cost of solar PV is relatively high, it is believed that, with technology improvements and the limitations facing other forms of energy, solar PV will become a mainstream energy source after 2030. We should therefore have enough confidence in its future potential to invest now in basic research, technology advances and industry development.

Because of its high cost, the development of the solar PV industry cannot be driven solely by the market. International experience shows that government support has been the major driver for the solar PV industry, and will have a great impact on its future development and market demand. It is therefore worthwhile analyzing the status of the technology worldwide, making a reasonable projection for its future in China and providing appropriate recommendations for policy makers.

With the support of Greenpeace, the Worldwide Fund for Nature and the European Photovoltaic Industry Association, the Chinese Renewable Energy Industry Association has compiled this report. Written by two acknowledged experts in the field, it analyses both global and domestic PV development and makes specific projections of future trends. As well as educating the public about solar PV, the report will provide valuable recommendations to policy makers and present an industrial blueprint.

Sincere appreciations go to the following experts, companies and institutions for their contributions to the report: Zhao Yuwen, Wu Dacheng, Zhu Junsheng, Cui Rongqiang, Wang Guohua, Xu Honghua, Lv Fang, Wang Yin, Dong Luying, Wang Zhongyin, Baoding Economic Zone, Suntech, Jike Energy New Technology Development Company.

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1.1 The solar potential

There is more than enough solar radiation available around the world to satisfy the demand for solar power systems. The proportion of the sun's rays that reaches the earth's surface can meet global energy consumption 10,000 times over. On average, each square meter of land is exposed to enough sunlight to receive 1,700 kWh of energy every year. The greater the available solar resource at a given location, the larger the quantity of electricity generated.①

1.2 What is photovoltaic energy?

Photovoltaic technology, the term used to describe the hardware that converts solar energy into electricity. At the heart of photovoltaic (PV) technology is a semi-conductor material which can be adapted to release electrons. The most common semi-conductor material used in photovoltaic cells is silicon, an element most commonly found in sand.

All PV cells have two layers of semi-conductors, one positively charged and one negatively charged. When light shines on the semi-conductor, the electric field across the junction between these two layers causes electricity to flow, generating DC (direct current). The greater the intensity of the light, the greater the flow of electricity. A photovoltaic system therefore does not need bright sunlight in order to operate. It can also generate electricity on cloudy days. Due to the reflection of sunlight, days with slight cloud can even result in higher energy yields than days with a completely cloudless sky.

1.3 PV technology

The most important parts of a PV system are the cells which form the basic building blocks of the unit, collecting the sun's light, the modules which bring together large numbers of cells into a unit, and, in some situations, the inverters used to convert the electricity generated into a form suitable for everyday use.

PV cells and modules

PV cells are generally made either from crystalline silicon, sliced from ingots or castings or from grown ribbons, or thin film, deposited in thin layers on a low-cost backing. Most cell production (93% in 2006) has so far involved the former, whilst future plans have a strong focus on the latter. Thin film technology based on silicon and other materials is expected to gain a much larger share of the PV market. This technology offers several advantages, such as low material consumption, low weight and a smooth appearance.

Crystalline silicon

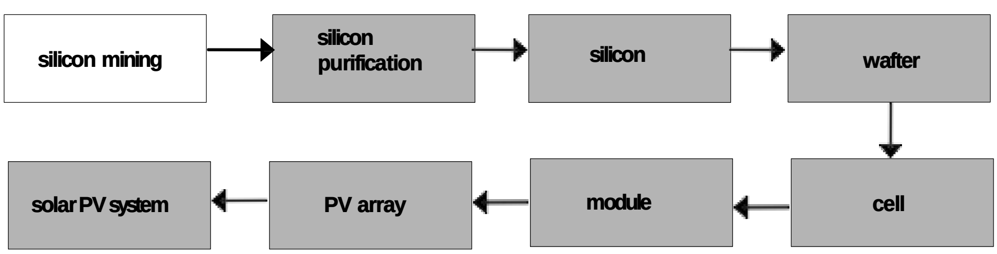
Crystalline silicon is still the mainstay of most PV modules. Although in some technical parameters it is not the ideal material for solar cells, it has the benefit of being widely available, well understood and uses the same technology developed for the electronics industry. Efficiencies of more than 20% have been obtained with silicon cells already in mass production. This means that 20% of the incoming insolation can be transferred into electricity.

As well as the efficiency of the solar cells, their thickness is also an important factor. Wafers - very thin slices of silicon - are the basis for crystalline solar cells. Thinner wafers mean less silicon needed per solar cell and therefore lower cost. The average thickness of wafers has been reduced from 0.32 mm in 2003 to 0.18 mm by 2007. Over the same period the average efficiency has increased from 14% to 16%. By 2010 the aim is to reduce wafer thickness to 0.15 mm whilst increasing efficiency to an average of 17.5%.

Thin film

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials on to a low cost backing such as glass, stainless steel or plastic. This results in lower production costs compared to the more material-intensive crystalline technology, a price advantage which is counterbalanced at the moment by substantially lower efficiency rates.

FIGURE 1 SOLAR PV PRODUCTION CHAIN



①EPIA, Roadmap of Solar PV Technology in Europe, 2007.

Three types of thin film modules are commercially available at the moment. These are manufactured from amorphous silicon (a-Si), copper indium diselenide (CIS, CIgS) and cadmium telluride (CdTe). All of these have active layers in the thickness range of less than a few microns. A temporary shortage of silicon has also offered the opportunity for increasing the market share of thin film technologies. The European Photovoltaic Industry Association (EPIA) expects the thin film market share to reach about 20% of the total production of PV modules by 2010.① Among the three commercially available thin film technologies, a-Si is the most important in terms of production and installation, with 4.7% of the total market in 2006.

Other cell types

Concentrator cells work by focusing light on to a small area using an optic concentrator such as a Fresnel lens, with a concentrating ratio of up to 1,000. This small area can then be equipped with a material made from III-V compound semiconductors (multi-junction gallium Arsenide type), which have efficiencies of 30% and in laboratories of up to 40%. The two main drawbacks with concentrator systems are that they cannot make use of diffuse sunlight and must always be directed very exactly towards the sun with a tracking system.

Modules

Modules are clusters of PV cells incorporated into a unit, usually by soldering them together under a sheet of glass. They can be adapted in size to the proposed site, and quickly installed. They are also robust, reliable and weatherproof. In central Europe a 3 kWp rated solar electricity system, with a module area of approximately 23 square metres, would produce enough power to meet the electricity demand of an energy-conscious household.

Inverters

Inverters are used to convert the direct current (DC) power generated by a PV generator into alternating current (AC) compatible with the local electricity distribution network. This is essential for grid-connected PV systems. Inverters are offered in a wide range of power classes, from a few hundred watts through the most frequently used range of several kW (3-6 kW) up to central inverters for large-scale systems with 100 kW and above.

1.4 Types of PV system

grid connected

This is the most popular type of solar PV system for homes and businesses in the developed world. Connection to the local electricity network allows any excess power produced to be sold to the utility. Electricity is then imported from the network outside daylight hours. An inverter is used to convert the DC power produced by the system to AC power for running normal electrical equipment.

In countries with a premium feed-in-tariff, payment for the electricity generated (see Chapter Seven: International Experience) is considerably higher than the usual tariff paid by the customer to the utility, so all the electricity produced is often fed into the public grid and sold to the utility. This is the situation in countries such as germany or Spain.

Off-grid

Where no mains electricity is available, the system is connected to a battery via a charge controller. This stores the electricity generated for future use and acts as the main power supply. An inverter can be used to provide AC power, enabling the use of normal electrical appliances. Typical off-grid applications are repeater stations for mobile phones, electrification for remote areas (mountain huts) or rural electrification in developing countries. Rural electrification means either small solar home systems covering basic electricity needs in a single household or larger solar mini-grids, which provide enough power for several homes.

hybridm system

A solar system can be combined with another source of power- a biomass generator, a wind turbine or diesel generator - to ensure a consistent supply of electricity. A hybrid system can be grid connected, stand alone or grid support.

In a single household or larger solar mini-grids, which provide enough power for several homes.

①EPIA, Roadmap of Solar PV Technology in Europe, 2007.

2 Solar Benefits

Photovoltaic power systems offer many unique benefits above and beyond simple energy delivery. That is why comparisons with conventional electricity generation - and more particularly comparison with the unit energy costs of conventional generation - are not always valid. If the amenity value of the energy service that PV provides, or other non-energy benefits, could be appropriately priced, the overall economics of PV generation would be dramatically improved in numerous applications, even in some grid-connected situations. PV also offers important social benefits in terms of climate and environmental protection, job creation and rural development.

2.1 Climate change

The most important feature of solar PV systems is that there are no emissions of carbon dioxide - the main gas responsible for global climate change - during their operation.

Recycling of PV modules is possible and raw materials can be reused. As a result, the energy input associated with PV will be further reduced.

Scientific Assessment of Climate Change

In February 2007 the Intergovernmental Panel on Climate Change (IPCC) released the first of a series of reports which make up its Fourth Assessment Report. "Climate Change 2007: The Physical Science Basis" assesses the current scientific knowledge of the natural and human drivers behind climate change, observed changes in climate, the ability of science to attribute changes to different causes, and projections for future climate change. This report expresses much greater confidence than past assessments that most of the observed warming over the past half-century is caused by human activities (greater than 90 % certainty) and concludes, from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea levels, that warming of the climate system is unequivocal.

Among the observed impacts detailed in the report are:

- *Eleven of the last twelve years rank among the twelve hottest on record.*
- *global sea level rise has accelerated.*
- *Mountain glaciers and snow cover have declined on average in both the northern and southern hemispheres.*
- *More intense and longer droughts have been observed over wider areas since the 1970s, particularly in the tropics and subtropics.*

The report concludes that if we take no action to reduce emissions, there will be twice as much warming over the next two decades than if we had stabilised heat-trapping gases at 2000 levels.

Among the projections included in the report are:

- *The range of projected temperature increase over the present century is 1.1 to 6.4 ℃.*
- *The best estimate range, which reflects the centre point of the lowest and highest emission scenarios, is for a 1.8 to 4.0 ℃ increase.*
- *It is likely that future tropical cyclones (typhoons and hurricanes) will become more intense, with higher peak wind speeds and more heavy precipitation associated with warmer tropical seas.*
- *There is a greater than 90 % likelihood that extreme heat, longer heat waves and heavy precipitation events will continue to become more frequent.*

Some of the report's key findings are:

- *It is likely that climate change will induce mass extinction of species within 60-70 years.*
- *Over the next decades the number of people at risk of water scarcity is likely to rise from tens of millions to billions. Steadily decreasing water availability is projected for India and other parts of South Asia and Africa. Whilst the poorest parts of the world are going to the hardest hit, wealthy countries such as Australia and nations in Southern Europe are also in the front line.*
- *Reductions in food production capacity in the poorest parts of the world are projected, bringing more hunger and misery and undermining achievement of the millennium development goals. Within a few decades it is likely that we will see climate change induced wheat, maize and rice production falls in India and China.*
- *Increased drought and water scarcity are likely to lead to growing problems of hunger and human dislocation in Africa over the coming decades.*
- *The loss of glaciers in Asia, latin America and Europe are set to cause major water supply problems for a large fraction of the world's population, as well as a massive increase in glacial lake outburst floods and other risks for those living in the glaciated mountains.*
- *huge numbers of people will be at risk due to sea level rise, storm surge and river flooding in the Asian megadeltas such as the ganges-Brahmaputra (Bangladesh) and the Zhujiang (China).*
- *Warming of more than another degree could commit the world to multi-metre sea level rise over several centuries from the partial or total loss of the greenland and West Antarctic ice sheets. huge coastal dislocation would result.*

If governments adopt a wider use of PV in their national energy generation, solar power can therefore make a substantial contribution towards international commitments to reduce emissions of greenhouse gases and their contribution to climate change.

2.2 Environmental protection

The environmental situation in China is more critical than in other countries. China can claim a major share of the top ten most polluting cities. Environmental pollution has brought serious impacts in terms of social and economic development as well as for human health. The main causes are a high proportion of coal use in the energy mix and a large amount of direct coal combustion (see Table 1). Energy consumption in China accounts for 10% of the world's total, but SO_2 emissions account for 15.1% of the total, the largest of any country. One third of China's land mass is polluted by acid rain①. According to estimates by the World Bank, damage to the environment and health induced by air pollution in China will amount to 10% of gDP by 2020②.

2.3 Space saving installations

PV is a simple, low-risk technology that can be installed virtually anywhere where there is available light. This means that there is a huge potential for the use of roofs or façades on public, private and industrial buildings. During their operation such systems can also help reduce buildings' heating loads or assist in ventilation through convection.

Other places where PV can be installed include the sound barriers along communication links such as motorways. In satisfying a significant part of the electricity needs of the industrialised world there will be no need to exploit otherwise undisturbed areas.

2.4 Employment

PV offers important social benefits in terms of job creation. Significantly, much of the employment creation is at the point of installation (installers, retailers and service engineers), giving a boost to local economies. Based on information provided by the industry, it has been assumed that 10 jobs are created per MWp of installed capacity during production and about 33 jobs per MWp during the process of installation. Wholesaling of the systems and indirect supply (for example in the production process) each create 3-4 jobs per MWp. Research adds another 1-2 jobs per MWp.

PV industry is also labour-intensive. Currently the industry offers employment to nearly 10,000 people. The number is expected to reach 100,000 by 2020 and to 5,000,000 by 2050, given that the total PV installed capacity could reach 1,000gWp.

2.5 Rural electrification

Solar power can be easily installed in remote and rural areas, places that may not be targeted for grid connection for many years. Renewable energy sources such as PV are currently one of the few suitable options to supply electricity in areas of dispersed communities or at a large distance from the grid. Decentralised (off-grid) rural electrification based on the installation of stand alone systems in rural households or the setting up of minigrids - where PV can be combined with other renewable energy technologies or with lPg / diesel - enables the provision of key services such as lighting, refrigeration, education, communication and health, thus increasing economic productivity and creating new income generation opportunities. Furthermore, the technologies which are used to power off-grid applications (stand alone PV systems, PV water pumping systems and hybrids) are often both affordable and environmentally sound. Due to their robustness, ease of installation and flexibility, PV systems are able to adapt to almost any rural energy demand in any part of the world. By the end of 2006, there were still 11 million people in China without access to electricity. Solar PV could help achieve a power supply for most of these people.

2.6 Universal electricity supply

A "policy driven" scenario drawn up by EPIA and greenpeace

TABlE 1 COMPARISOn OF PRIMARy EnERgy MIx In ChInA AnD ThE WORlD

	World	China
Coal	28.4%	70.2%
Oil	35.8%	20.6%
natura gas	23.7%	2.9%
nuclear	5.8%	0.7%
hydro	6.3%	5.6%

①National Development and Reform Commission, Mid-to-long-term Energy Saving Plan, 2004.

②Janet L.Sawin. Renewable Energy World Review 2005.

(Solar generation IV, 2007) shows that by 2030 PV systems could be generating approximately 1,500 TWh of electricity around the world. This means that enough solar power would be produced globally to supply more than half of the current Eu electricity needs or replace 300 coal-fired power plants (average size 750 MWp). global installed capacity of solar power systems could reach 1,300 gWp by 2030. About two thirds of this would be in the grid-connected market, mainly in industrialised countries. Assuming that 80% of these systems are installed on residential buildings, and their average consumption per three person household is 3,500 kWh, the total number of people by then generating their electricity from a grid-connected solar system would reach 1 billion.

Although the key solar PV markets are currently located mainly in the industrialised world, a global shift will result in a significant share being taken by the now developing world in the future. There are 2 billion people globally who have no access to electricity. Providing electricity to all is a part of the "millennium goal" to build a harmonious human society. The Declaration from the World Renewable Energy Conference held in Bonn in 2004 called for the development of solar PV to provide electricity to 1 billion people with no access to electricity.[1] This is a big potential market for solar PV.

2.7 China's energy balance

China is a major energy producer as well as a major energy consumer. Total energy consumption in 2006 was 2,460 million tons of coal equivalent (tce), 9.3% more than in 2005. Of this total, coal, oil and natural gas accounted for 69.7%, 20.3% and 3% respectively, with 6% and 0.8% coming from hydro and nuclear power. In 2006, China imported 150 million tons of crude oil, about 50% of the country's total demand (see Figure 2).

Technologies used for both energy exploitation and energy utilisation in China are in urgent need of modernisation. A large portfolio is used by the energy intensive industries. unit energy use per gDP is the highest in the world,[2] far above the developed countries and much higher than the world average. Moreover, China is the largest developing country in the world, with rapid economic growth. This has resulted in a very fast increase in demand, making energy substitution even more important.

The Chinese Electric Power Research Institute made an analysis of expected future power supply development as part of the national Medium and long-Term Development Plan of the 11th Five-year Plan. The results show that even with the fullest use of coal-fired, hydroelectric and nuclear power, there will still be a gap in electricity supply of 6.4% and 10.7% respectively in 2010 and 2020, [3] as shown in Figure 3. This gap needs to be filled by renewable energy. however, if there is no mandatory encouragement for renewable energy through the implementation of a Renewable Energy law, it will fail to fulfill this expectation.

FIguRE 2 ChInA'S PRIMARy EnERgy MIx, 2006

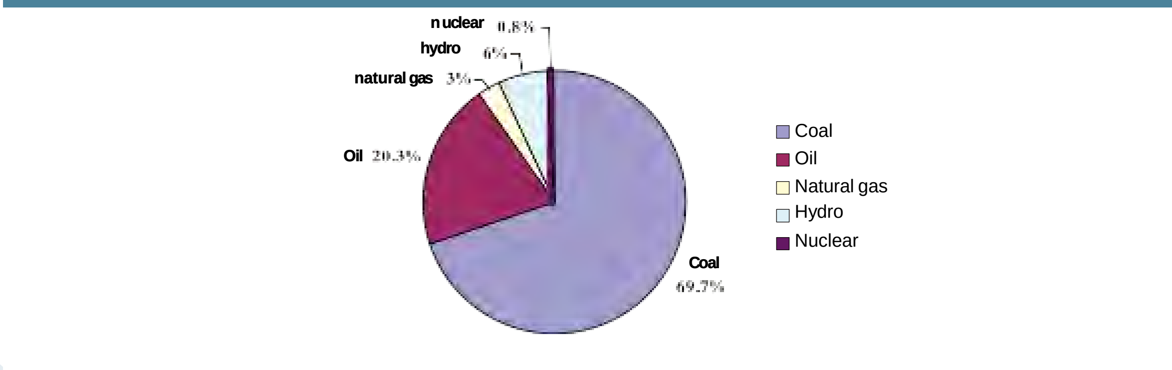
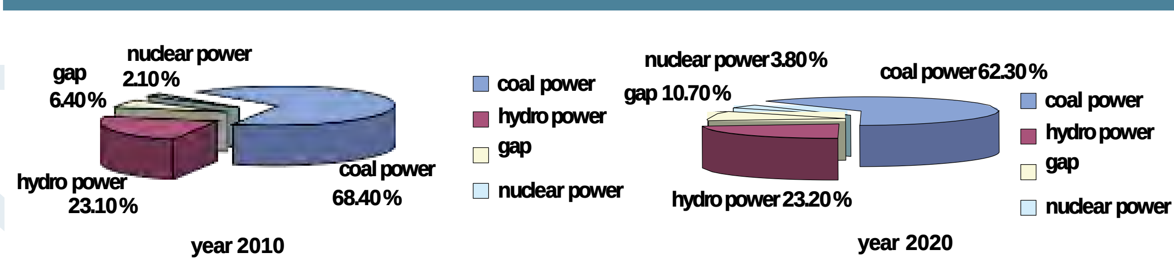


FIguRE 3 ElECTRICITy gEnERATIOn MIx In 2010 AnD 2020 (ChInESE ElECTRIC POWER RESEARCh InSTITuTE)



①Declaration from the World Renewable Energy Conference , Bonn , 2004.
②National Development and Reform Commission, Mid-to-long-term Energy Saving Plan, 2004.
③Hu Xuehao, Report on China' s Mid and Long Term Energy Strategy, 2004.

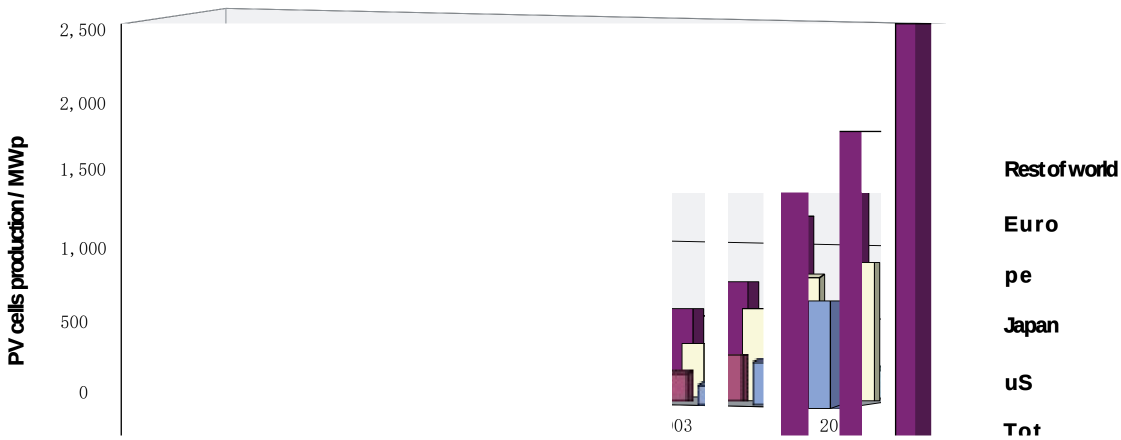
3 Global PV Development Profile and Trends

3.1 Worldwide PV industry and market development

Increasing concern for energy and environmental issues has been seen around the world in recent years. In order to satisfy energy demand and ensure sustainable development, many countries have turned to PV power generation as one of the options. The PV industry has therefore been growing rapidly with government support, reaching an average annual growth rate of 33% for PV cells production over the past ten years. During the last five years, the average growth rate has even reached 43%, with 2,500 MWp of solar cells produced in 2006. Cumulative shipments of cells have now reached 8,500 MWp.①

China was the third largest country for PV cell production, after Japan and germany, in 2006, with an annual production of

FIguRE 4 WORlDWIDE AnnuAl PRODuCTIOn OF PV CEllS

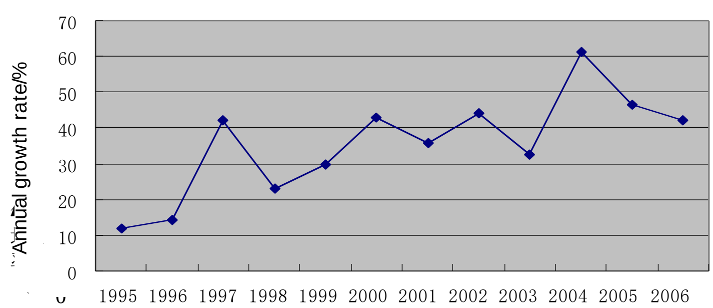


	1990	1992	1994	1996	1998	1999	2000	2001	2002	2003	2004	2005	2006
Rest of world	4.7	4.6	5.6	9.75	18.7	20.5	23.42	32.6	55	83.8	139	302	714
Europe	10.2	16.4	21.7	18.8	33.5	40	60.66	86.38	135	193.4	314	470	657
Japan	16.8	18.8	16.5	21.2	49	80	128.6	171.2	251	363.9	602	833	928
uS	14.8	18.1	25.64	38.85	53.7	60.8	74.97	100.3	120	103.2	140	154	202
Total	46.5	57.9	69.44	88.6	154.9	201.3	287.7	390.5	561	744.3	1,195	1,759	2,500

TABlE 2 WORlDWIDE SOlAR CEll SAlES AnD CuMulATIVE PV uSE FROM 1997-2006/gWp

year	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Annual production	0.126	0.155	0.201	0.287	0.391	0.561	0.744	1.2	1.76	2.5
Annual growth rate /%	42	23.1	30	42.9	35.7	44	32.5	61.2	46.7	42
Cumulative use	0.791	0.946	1.147	1.435	1.825	2.387	3.131	4.331	6.09	8.59

FIguRE 5 AnnuAl gROWTh RATE OF WORlDWIDE SOlAR CEll PRODuCTIOn



① Paul Maycock, PV News, 2007.

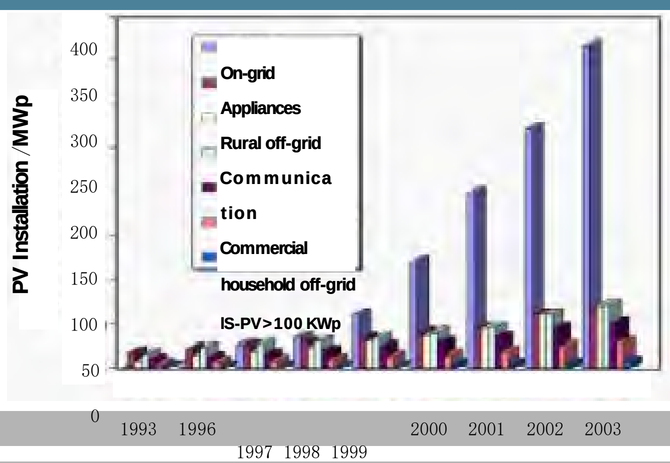
369.5 MWp. Figure 4 shows the increase in global solar PV cell production since 1990. Table 2 shows worldwide annual sales of cells and cumulative use of PV electricity in gWp. Table 3 shows the world's top 16 manufacturers of solar cells.

One of the most outstanding features of the global development of the PV industry is the increasingly important contribution which PV power generation has been able to make in replacing conventional energy supply. This is evidenced by the rapid increase of its use as grid-connected power generation, which has become the dominant sector in the PV market. Other uses include communications and signals, special commercial and industrial uses, rural distributed power systems, consumer products and large-scale independent power station, as shown in Figure 6. Table 4 shows the increase of grid-connected PV power generation.①

TABLE 3 TOP 16 SOLAR CELL MANUFACTURERS IN 2005 AND 2006

Manufacturer	Production 2005 /MWp	Percentage / %	Rank 2005	Production 2006 /MWp	Percentage / %	Rank 2006
Sharp	428.0	24.3	1	434	17.4	1
Q-Cell	166.0	9.4	2	253	10.1	2
Kyocera	142.0	8.1	3	180	7.2	3
Suntech	82.0	4.7	9	158	6.3	4
Sanyo	125.0	7.1	4	155	6.2	5
Misubishi	100.0	5.7	5	111	4.4	6
Motech	60.0	3.4	10	110	4.4	7
Schott	95.0	5.4	7	96	3.8	8
Solar World	97.0	5.5	6	86	3.4	9
BP Solar	88.0	5.0	8	85.7	3.4	10
Sun Power	23.0	1.3	NR	63	2.5	11
Isofoton	63.0	3.6	11	61	2.4	12
First Solar	20.0	1.1	NR	60	2.4	13
nanjing	7.0	0.4	NR	60	2.4	14
Ersolr	20.0	1.1	NR	40	1.6	15
Photowatt	24.0	1.4	12	24	1.0	16
ROW	2,52.0	14.3		524	21.0	
World	1,760	100.0		2,500	100.0	

FIguRE 6 WORIDWIDE PV APPIICATIOn BREAKDOWn By SECTOR



TABIE 4 OVERVIEW OF InCREASIng ShARE OF gRID-COnnECTED PV

year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
Market percentage / %	7.9	21.3	23.5	29.9	41.7	50.4	51.4	55.5	65.9	>70

① II

3.2 World PV development goals and perspectives

germany, Japan and the united States have made the largest contribution to the market development of PV power generation because of the incentives these countries have implemented. Currently, over 70% of solar cells are used for grid-connected power generation systems. The uS, Japan and the Southern European union have all laid down their respective PV development targets. Tables 5 and 6 show cost estimates for PV power generation and the development routes of the major countries, alongside the current goal for China.①

Table 6 shows that the development objectives for the Chinese PV market are not ambitious.

In the long run, it is expected that solar PV power generation will not only play a significant part in world energy consumption but will also replace a substantial part of the conventional fuels which currently dominate supply. According to a projection by the European Commission's Joint Research Centre, renewable energy could contribute over 30% of the energy mix by 2030, within which solar PV power generation would satisfy over 10% of electricity supply.

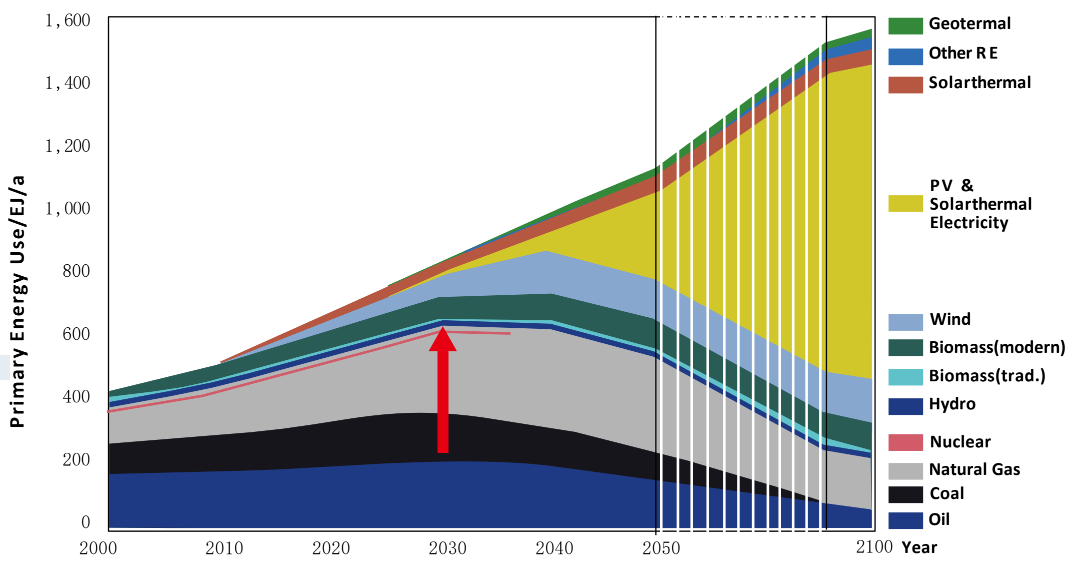
TABlE 5 PV POWER gEnERATIOn COSTS ESTIMATES

year	2004	2010	2020
Japan (yen/kW.h)	30	23	14
Southern Europe (Euro/kW.h)	0.25	0.18	0.10
uS (¢/kW.h)	18.2	13.4	10.0
China (yuan/kW.h)	5.0	3.0	1.4

TABlE 6 PV InSTAllED CAPACITy ESTIMATES /gWp

year	2004	2010	2020
Japan	1.2	4.8	30
Europe	1.2	3.0	41
uS	0.34	2.1	36
China	0.065	0.3	1.8
Others	1.195	3.8	91.2
World total	4.0	14	200

FIguRE 7 EnERgy SuPPly PROJECTIOn By EuROPEAn COMMISSIOn'S JOInT RESEARCh CEnTRE



① Allen Barnett, US PV Industry Roadmap 2001, Japanese PV Roadmap Towards 2030, NEDO 2004, Winfried Hoffmannl, EU PV Industry Roadmap 2004.

3.3 Development trends in world solar PV technology

Technical improvement is the key factor that reduces the cost of PV power generation, and encourages the PV industry's market development. Over the past decades there have been considerable achievements in terms of both R&D and technology advances, in particular the increase in cell efficiency, the production of thinner silicon and the improvement of production processes. All these have played a decisive role in PV power generation cost reduction.

3.3.1 Increase in cell efficiency

laboratory cells

The laboratory efficiency of mono-crystalline silicon has improved from 6% in the 1950s to 24.7% now. The laboratory efficiency of polysilicon cells has also reached 20.3%. Equal success has been achieved in research into the use of thin film cells, so that the laboratory efficiency of amorphous thin film cells has stabilised at 13.9%, whilst that of CdTe has reached 16.4% and that of CIS 19.5%.

There has also been progress in the development of other new types of cells, such as polycrystalline silicon thin film, dye-sensitised photoelectrochemical and organic cells. These new-concept cells with higher efficiencies have created considerable interest. Table 7 shows the highest laboratory efficiency of various kinds of solar cells.

Commercialised solar cells

As advanced technologies have been introduced into the industry, the efficiencies of commercial cells have continuously improved. At present, the efficiency of commercial crystalline silicon solar cells has reached 14%-20%, whilst mono-crystalline solar cells have reached 16%-20% and polycrystalline silicon cells 14%-16%. Meanwhile, PV manufacturing and system integration technologies have kept pace, together stimulating both a decrease in the cost of PV power and the continual development of the PV market and industry.

3.3.2 Decrease in the thickness of commercial solar grade silicon wafers

Decreasing the thickness of silicon wafers is an effective way to reduce consumption of silicon and the cost of crystalline silicon solar cells. It is therefore an important focus in the improvement of PV technologies. The thickness of solar grade silicon wafers has decreased by more than half, falling from 450-500 μm in 1970 to 180-280 μm now. The consumption of silicon material has therefore been greatly reduced. This is a useful demonstration of how technology improvement can reduce cost. The decreasing trend in the thickness of silicon wafers is shown in Table 8.

TABIE 7 IABORATORy EFFICIEnCy OF VARIOuS SOIAR PV CEIIS

Type	Conversion efficiency	laboratory	note
mono-crystalline silicon cell	24.7±0.5	South Wales University, Australia	4cm^2 area
Back surface contact mono-crystalline silicon cell	26.8±0.8	SunPower, US	96times concentrating
gaAs hetero-junction cell	40.7±1.7	Spectrolab	Concentrating solar cell
polycrystalline silicon cell	20.3±0.5	Fraunhofer Institute, Germany	1.002cm^2 area
IngaP/gaAs	30.28±1.2	Japan Energy Company	4cm^2 area
amorphous solar cell	14.5 (initial) ±0.7 12.8 (steady) ±0.7	USSC, US	0.27cm^2 area
CIgS	19.5±0.6	National Renewable Energy Laboratory, US	0.410cm^2 area
CdTe	16.5±0.5	National Renewable Energy Laboratory, US	1.032cm^2 area
Polycrystalline thin film solar cell	16.6±0.4	Stuttgart University, Germany	4.017cm^2 area
na-si solar cell	10.1±0.2	Kaneka, Japan	0.002mm film
dye-sensitised photoelectrochemical cell	11.0±0.5	EPFL	0.25cm^2 area
hIT	21.5	Sanyo, Japan	

TABIE 8 DECREASE In ThE ThICKnESS OF SOIAR gRADE SI WAFERS

Period	Thickness /μm	Consumption of silicon materials / Ton/MWp
1970s	450-500	>20
1980s	400-450	16-20
1990s	350-400	13-16
Present	180-280	12-13
2010	150-180	10-11
2020	80-100	8-10

3.3.3 Increases in scale of production

The continuous enlargement of the scale of production, and an increase in the degree of automation, are both important factors in the reduction of solar cell production costs. The scale of solar cell production at a single factory has been increased from 1-5 MWp/year in the 1980s to 5-30 MWp/ year in the 1990s and then to 50-500 MWp/year in this century. The relationship between the scale of production and cost reduction can be illustrated by the learning Curve Rate (IR), which predicts a decrease in production cost when the scale of production doubles. For solar cells, data collected over 30 years shows that IR=20% (including the effect of technology improvement), which is the largest amongst all the renewable power generation sources, and serves as one of the best examples of modern intensive production methods. It is expected that a single factory will be able to produce an annual capacity of 1 gWp within two years.

3.3.4 Decreases in the cost of solar PV modules

The cost of PV modules has decreased by two orders of magnitude, as shown in Figure 8.① In 2003, the cost of production by major manufacturers was $2 -2.3 /Wp, and the selling price was $2.5-3 /Wp. Recently, the price has risen due to a lack of raw materials. When the relationship between supply and demand changes and costs fall again, the cost will probably be lower than at the corresponding point in the last cycle. This cycle has occurred previously over the last three decades.

3.3.5 Advances in crystalline and thin-film solar cells

Figure 9 illustrates the market shares of various kinds of solar cells in 2004. Polycrystalline silicon solar cells accounted for 56%, mono-crystalline silicon solar cells for 29%, hIT solar cells (amorphous silicon (p-type) / mono-crystalline silicon (n-type)/ heterojunction solar cells) for 5%, ribbon silicon solar cells for 3% and thin-film solar cells for 7%. The market share of polycrystalline silicon solar cells has been increasing for a long time. It exceeded the market share of mono-crystalline silicon solar cells in 1998. The production of various thin- film cells has also been increasing steadily in recent years,② reflecting progress in the technology.

FIgURE 8 FAllIng COST OF PV MODulES

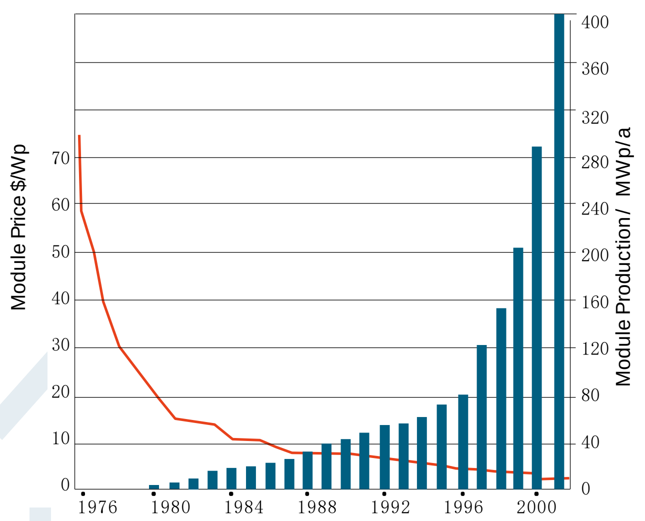
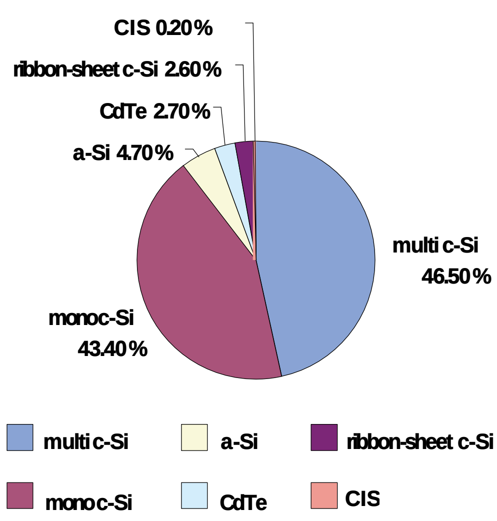


FIgURE 9 CEll TEChnOlOgy ShARES In 2006



① REDP World Bank, PV Development in China, 2005.

② Photon International, 2007.

4 Status of China' s Solar PV Market and Production

In the Chinese domestic market, solar cells are mainly used for rural electrification, communications and industrial purposes, as well as for road signs and lighting. Since the current price is comparatively high, the market is still under development.

The solar PV industry in China involves production of polycrystalline silicon as a raw material, silicon wafer production, solar cell production, module encapsulation and other related processes such as the manufacture of specialised materials and equipment, testing equipment and balance-of-system components.

4.1 PV Power Market in China

China started solar cell research in 1958 and the first successful application of solar cells was in a satellite called the "no. 2 East Red Satellite" in 1971. The terrestrial application of solar cells started in 1973. limited by high price, the initial development of the PV market was quite slow, with the main application being to provide power for satellites.

The terrestrial application of solar cells was at first only for small power systems such as beacon lights, railway signal systems, weather stations on mountains, electric fences for stock enclosure, insect trapping lights and DC solar lights. These had a power level from several watts up to a few tens of watts. During the period of the 6th (1981-1985) and 7th (1986-1990) Five-year Plans, the Chinese government started to support demonstration uses of PV applications. The PV industry was promoted in specialised industries and rural areas, for example in solar powered microwave relay stations, military communication systems, cathode protection systems for sluice gates and oil pipelines, carrier wave telephone systems in rural areas, small-scale solar household systems and central power supply systems in villages.

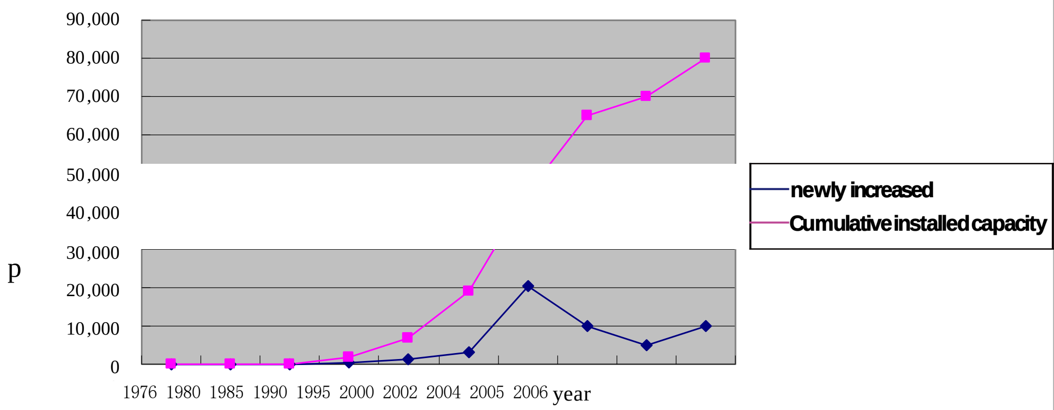
In 2002, the national Development and Planning Commission the Township Electrification Programme (Song Dian Dao xiang), which was aimed at solving power supply problems by using PV and small-scale wind electricity generation in more than 700 townships in seven western provinces (Tibet, xinjiang, Qinghai, gansu, Inner Mongolia, Shanxi and Sichuan). Total PV consumption was 15.5 MWp. This programme has stimulated the PV industry and several production assembly lines have been established, rapidly increasing the annual production of solar cells to 100 MWp (from 20 MWp in 2002). By the end of 2003, the cumulative installed capacity of solar PV had reached 55 MWp.

Between 2003 and 2005 the European PV market, especially the german market, further encouraged the rapid development of production capacity in China. By the end of 2005, total production capacity of solar PV modules had reached 400 MWp, of which 140 MWp was manufactured in 2005 alone. Most of these modules are exported to the European market, with only 5 MWp in 2005 and 10 MWp in 2006 installed in China. Table 9 and Figure 10 give an overview of development of the Chinese PV market.①

TABlE 9 PV MARKET DEVElOPMEnT In ChInA SInCE 1976

year	1976	1980	1985	1990	1995	2000	2002	2004	2005	2006
Annual installed Capacity /kWp	0.5	8	70	500	1,550	3,300	20,300	10,000	5,000	10,000
Cumulative installed Capacity /kWp	0.5	16.5	200	1,780	6,630	19,000	45,000	65,000	70,000	80,000

Figure 10 AnnuAl nEW AnD CuMulATIVE InSTAllED PV CAPACITy In ChInA



① Wang Sicheng, "Research on China's Solar PV". China Energy, Vol2, 2007, pp.7-10.

4.2 PV Market Breakdown

By the end of 2006, the cumulative installed capacity of solar cells had reached 80 MWp. The market for PV power generation is mainly composed of communications, industrial applications, rural off-grid supply, grid connected systems and small solar products. The breakdown is shown in Table 10 and Figure 11.①

Among all these applications, about 53.8% is located in the commercial sector (telecommunications, industrial applications and solar PV appliances), whilst the remaining 46.2% requires support from the government (rural electrification and grid-connected generation).

4.3 Current Status of PV industry

Currently, 85% of the world market is taken by crystalline sil icon solar cells, including mono- crystalline and polycrystalline cells. Other types of cells, such as amorphous silicon, CdTe, CTS solar cells, have a small share. When looking at the industrial supply chain, the main focus is therefore on crystalline solar cells.

4.3.1 Status of the polycrystalline silicon industry

During the development process of PV technologies, crystalline silicon solar cells have always been in the mainstream of commercial production. In the global market, over 98% of solar cells are made of high purity polycrystalline silicon. As the basic feedstock of solar cells, the manufacture of high purity polycrystalline is therefore the most important point in the whole PV industrial chain.

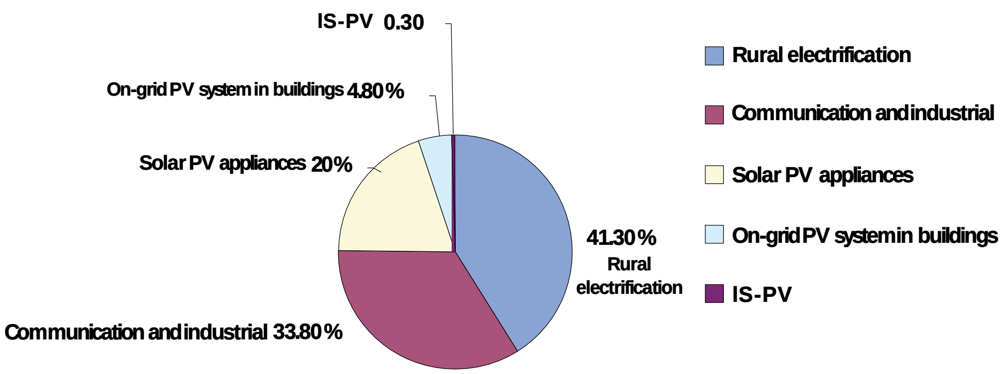
With the increasing growth of the PV industry, however, a shortage of polycrystalline silicon is becoming a serious problem. lack of supply means that the price of the feedstock has been increasing. In the period from 2001 to 2003, the global price of polycrystalline silicon feedstock was approximately $40/kg for electronic grade and $25/kg for solar grade. Since 2004, the price has continued to increase, to the point where it has reached $50/kg in the world market and over $100/kg on the black market. In 2006, the price was even more than $200/kg through informal channels.

The advanced technologies for polycrystalline silicon feedstock production are currently controlled by eight main manufacturers. For various reasons (manufacturers' uncertainty about the stability of the PV industry, desire for technical and market monopolisation, lack of industrial expansion), the supply of feedstock has lagged far behind the demands of the PV industry. This has led to the ongoing

TABIE 10 ChInA'S PV MARKET BREAKDOWn In 2006

Market sector	Installed capacity /MWp	Market share / %
Rural electrification	33	41.3
Communication and industrial applications	27	33.8
Solar PV appliances	16	20.0
On-grid PV system in buildings	3.8	4.8
large scale power station in desert	0.2	0.3
Total	80	100

FIguRE 11 MARKET ShARES OF PV POWER In 2006



① Wang Sicheng, "Research on China's Solar PV". *China Energy*, Vol2, 2007, pp.7-10 shortage of polycrystalline silicon feedstock all over the world. It is expected that this situation will last for at least another two years. Production of polycrystalline silicon feedstock has therefore become the bottleneck in the whole PV industrial chain, which not only limits any increase in solar cell production but also keeps the cost of solar cells at $3-4/ Wp, causing severe limitations in the PV industry's market development.

The present problems in China's polycrystalline silicon feedstock industry include:

1)Backward techniques: The main production techniques are based on an improved Siemens process, but this is old technology and energy consumption is about 1.5-2 times that of the world's more advanced processes.

2)Small production scale: Polycrystalline silicon manufacture is an industry with a strong correlation between production scale and manufacturing cost. The critical scale is commonly considered to be 2,000 tons/year; enterprises with production of less than 1,000 tons/year are considered uneconomical.

In 2006, China's annual polycrystalline silicon production capacity was 400 tons (luoyang Silicon 300 tons and Sichuan Emei 100 tons), although actual production is 300 tons, which could only meet the needs of 30 MWp of solar cells. There is a hug gap between production and demand, hence the industry is largely dependent on imports.

Both luoyang Silicon high-Tech and Sichuan Emei Semiconductor factories are currently enlarging their production capacities, whilst Sichuan xinguang has a plant under construction and will soon begin production. If these projects can be accomplished as scheduled, annual production capacity will be nearly 18,000 tons by 2008 and the severe lack of polycrystalline silicon feedstock in China will effectively be alleviated.

TABlE 11 PROJECTS In ThE POlyCRySTAllInE SIlICOn InDuSTRy In ChInA

Status	Company	Planned production capacity /tons/year	Phase I production capacity /tons/year	Production capacity by category /tons/year
Completed	Luoyang Zhonggui	300	300	500
	Emei Semi-conductor Factory	1,000	200	
under implementation	Leshan Xingguang Silicon Co.	1,260	1,260	9,260
	Luoyang Zhonggui Phase II	3,000	1,000	
	Yunnan Qujing Erisson	10,000	1,000	
	Fujian Guixing Silicon Co.	200	200	
	Chongqing Wanzhou (Jiangsu Daquan)	6,000	1,500	
	Yangzhou Shunda	6,000	1,500	
	Xuzhou (Zhonghua Silicon)	1,000	1,000	
	Asian Silicon (Qinghai-Wuxi Suntech)	6,000	1,500	
	Wuxi Zhongcai Group	300	300	
Proposed	Sichuan Leshan (Tongwei Group)	10,000	1,000	9,000
	Hubei Jingmen (Wuhan Jiawei)	1,500	1,500	
	Hunan Yichang (Shenzhen Nanbo)	4,500	1,000	
	Liaoning Jinzhou Longhai	1,000	1,000	
	Ningxia Shizuishang	4,000	1,000	
	Inner Mongolia Huhehot (Shanghai Shenzhou)	1,500	1,500	
	Hunan Yiyang	5,000	1,000	
	Qinghai Dongshuan (Huanghe Hydropower)	1,000	1,000	
Total		63,560	18,760	18,760

Note: First phase production capacity could be realised by the end of 2008.

4.3.2 Status of the Crystalline Silicon Ingot Manufacturing Industry in China

Silicon ingot slicing, i.e. silicon wafer production, is the first step in manufacturing crystalline silicon solar cells. Silicon wafers account for 65% of the cost of a crystalline silicon cell, whilst cell production and module encapsulation only represent 10% and 25% respectively. With the continual increase in silicon feedstock cost, silicon ingot cutting technology has also gained higher significance in solar cell manufacture. It has become a focus of concern in the PV industry to reduce silicon wafer costs and economise on the feedstock through technology improvement and equipments and process adjustment (see Figure 12).①

China' s crystalline silicon manufacturing industry has the following features:

- Rapid development: The annual average rate of increase has been more than 70% over the past few years.
- high dependence on imported feedstock: Because there is no polycrystalline silicon feedstock available domestically, China depends on imported materials. lack of feedstock and high prices in the international market have affected the development of domestic enterprises and resulted in some running at less than their production capacities.
- The techniques are relatively mature and the quality of production is no worse than that of foreign enterprises.
- Production of mono-crystalline silicon dominates: In the global PV industry, the ratio of mono-crystalline silicon to polycrystalline silicon is about 1:2.0 (2006); but production of mono-crystalline silicon materials is dominant in China. The major reason is that the Cz-silicon technique is relatively mature and mono-crystalline furnaces can be made domestically and hence are cheap, whereas polycrystalline silicon casting furnaces are imported and therefore expensive. For Cz-silicon the investment required is smaller, the construction period shorter and the funds can be recovered faster. Therefore silicon feedstock manufacturers tend to choose a mono-crystalline furnace that costs several hundred thousand yuan over a casting furnace that costs several million yuan.

FIguRE 12 ChAngES In SIlICOn FEEDSTOCK COnSuMPTIOn FOR SOlAR CEllS

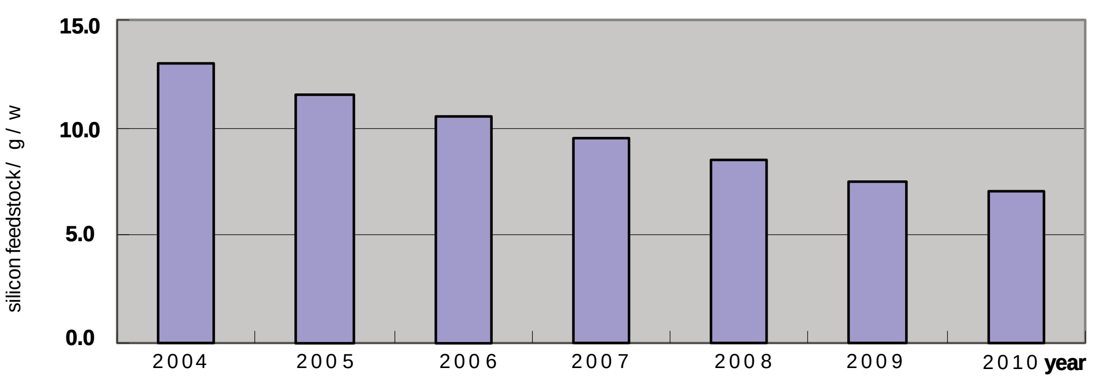


TABlE 12 MAnuFACTuRIng CAPACITy AnD ACTuAl PRODuCTIOn OF SOlAR gRADE SIlICOn In ChInA, 2006

Manufacturer	Material Type	Annual Production Capacity / Tons	Actual Production / Tons
hebei ningjin Jinglong Semiconductor Factory	Mono-crystalline silicon	2,250	1,126
Jinzhou huari Silicon Material Co. ltd.	Mono-crystalline silicon	800	400
Changzhou Trina Solar Co. ltd	Mono-crystalline silicon	180	60
Qinghai new Energy Research Institute Co. ltd.	Mono-crystalline silicon	270	0
Jiangxi Saiwei lDK	Polycrystalline silicon	3,000	100
Tianwei yingli new Energy Recourses Co. ltd.	Polycrystalline silicon	770	260
Zhejiang Sino-Italian Photovoltaic Co. ltd.	Polycrystalline silicon	90	40
Jiangsu Shunda group	Mono-crystalline silicon	350	100
Jinggong Shaoxing Solar energy Co. ltd.	Polycrystalline silicon	132	0
Others	Mono-crystalline silicon	3,000	400
Total	10,842 (Mono-crystalline silicon 6,850, Polycrystalline silicon 3,992)		2,486 (Mono-crystalline silicon 2,086, polycrystalline silicon 400)

① Cui Rongqiang, *Latest Developments in Solar PV*, 3rd Solar Silicon Conference, 2007.

The total production capacity for mono-crystalline silicon and polycrystalline silicon cast ingots was more than 10,000 tons in 2006. The table below only lists some of the silicon ingot/wafer manufacturers in China. According to a report in *Ireland Business* Wire (May 2007) there were 58 silicon ingot manufacturers and 38 silicon wafer ingot manufacturers with an estimated total capacity of over 15,000 tons.[①]

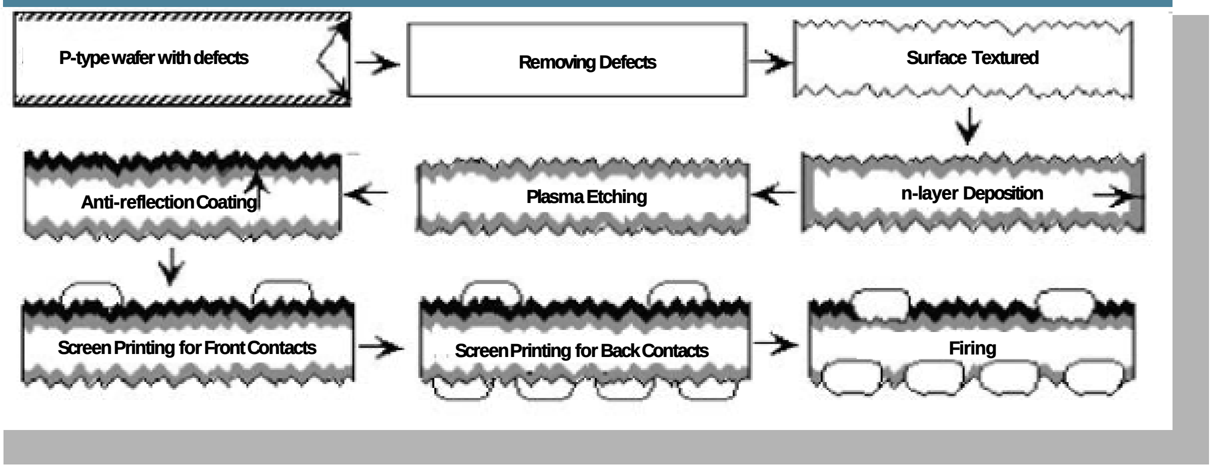
4.3.3 Status of the crystalline silicon solar cell manufacturing industry

Crystalline silicon solar cells are made through diffusion on mono-crystalline or polycrystalline silicon wafers. Commercial crystalline silicon solar cells use similar technologies, which can be seen in Figure 13.

In 2004, the annual production of solar cells in China was over 50 MWp, which was four times that of the year before; in 2005, production was nearly 130 MWp and in 2006 it reached 369.5 MWp. If there was not a restriction due to the lack of feedstock, development would be even faster. When the company Wuxi Suntech, for example, was listed on the new york stock exchange it proved extremely popular, leading to fresh investment in the solar cell industry by many businesses. By the end of 2006, the annual production capacity of solar cells in China had reached 1.6 gWp.

Although the manufacturing process in China is beginning to reach an advanced international level, most of the companies lack their own R&D capacity and rely on introducing equipment from abroad. As crystalline silicon solar cells have tended to become even thinner and highly efficient, the performance of home-made solar cells needs to be improved to be more competitive. These problems remain to be tackled.

FIguRE 13 TEChnOlOgy PROCESS OF MAnuFACTuRIng COMMERCIAl CRySTAllInE SIlICOn SOlAR CEllS



Suntech, leader in China's solar PV industry

Suntech is involved in developing, manufacturing and selling crystalline solar cells, modules and systems. The company was founded by Dr. Shi Zhengrong in 2001, when he came back from Australia with knowledge and experience in solar PV. With continuous technology innovation, the products' quality is still improving. Suntech is now listed on the new york Stock Exchange, the first time for a non uS-owned hi-tech company. According to PhOTOn International, Suntech was the eighth largest solar cell producer worldwide in 2005, and in 2006 it was among the Top 4. Suntech's products are exported globally, especially to Europe, the uS, the Middle East, Africa and Southeast Asia. In the domestic market, its products are used in communications, transport, lighting and military areas. Suntech has participated in the West lighting Project and BIPV applications.

① DUBLIN, Ireland, May 18, 2007 (BUSINESS WIRE).

4.3.4 Status of amorphous silicon solar cell manufacturing industry

Apart from those listed in Table 13, there are a number of other companies which are about to produce amorphous silicon cells. These include 10 MWp from guangdong Zhongshan, 10 MWp from Fujian Quanzhou, 10 MWp from Zhejiang Cixi, 5 MWp from lanxing and 2.5 MWp from Shandong Dongying. This shows good prospects for the development of amorphous silicon cell production.

4.3.5 Status of module encapsulation industry

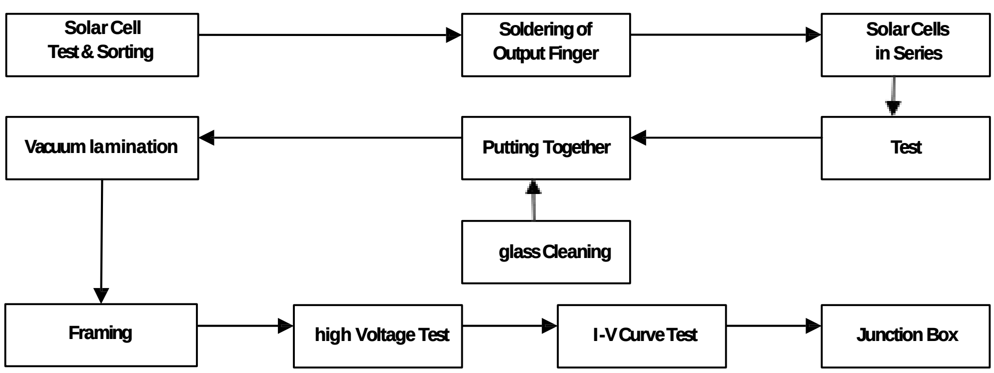
The main processes involved in crystalline silicon solar cell module manufacture are single chip connection and the encapsulation of crystalline silicon solar cells so as to protect electrode linking, prevent the connection line from erosion and avoid breaking cells. The quality of encapsulation directly affects the lifespan of the modules.

The solar cell encapsulation industry is currently the most mature in the whole PV industry chain, with the highest level of domestically manufactured equipment. This part of the industrial chain also requires the lowest entry investment, so that most enterprises are engaged in rapid production enlargement and a high productivity rate. As the domestic PV module market has not yet seriously started up, most of the modules are exported to other countries, especially Eu memberstates. however, there is nowsurplus encapsulation

TABIE 13 PRODuCTIOn OF AMORPhOuS SIlICOn SOIAR CEIIS In ChInA, 2005

Product	Manufacturer	Production (MWp)
Amorphous silicon	Haerbin Keluola	1
	Shenzhen Chuangyi	5
	Shenzhen Riyuehua	2
	Shenzhen Topray Solar Co. Ltd.	20
	Tianjin Jinneng	7.5
	Beijing Shihua	10
Total		45.5

FIguRE 14 ThE TEChnICAl PROCESS OF MODulE EnCAPSulATIOn



capacity in China due to the lack of upstream silicon feedstock. Thus the profit potential is small and quality varies a lot. The opportunity for competition in the international market is limited.

4.3.6 Balance-of-system (BOS) components

Balance-of-system (BOS) components mainly include the power controller, inverter and storage battery.

In manufacturing these components, China is at the same technical level and product quality standard as foreign producers for storage batteries, but there is still a gap with international standards for controllers and inverters, especially in terms of industry scale, product reliability and performance.

4.3.7 Status of PV-powered appliances and power generating systems

At present, the main PV-powered products are solar street lights, traffic signals, garden lamps, calculators and solar toys. Because of demand from the international market and the labour-intensive nature of the industry, many PV appliance manufacturers have become established in the Zhujiang Delta and coastal regions such as Fujian and Zhejiang. China has now become the largest producer of PV-powered products in the world.

At the end of 2006, the city of Beijing started its "lighting-up Programme", encouraging solar street lights in the construction of new rural developments. Beijing Municipal Science & Technology Commission has also launched a "Solar lighting in 100 Villages" Project. This has invested 250 million yuan in 13 counties and districts in the rural area of Beijng and installed nearly 40,000 lights. The project lasts for three years. Encouraged by these projects, many companies have moved into solar PV product manufacture. It is estimated that there are now at least 200 companies involved in the manufacture of solar street lamps, lawn lamps and other products. With almost no solar PV product manufacturing in other countries, China exports a high proportion of its output.

PV power generation was limited before 2000, and there were only a few manufacturers, located in the north-west of the country, with household PV systems as their main products. Since the inception of a "China Brightness Programme" by the State Planning and Reform Commission, hosting companies were established in several western provinces, including xinjiang, gansu, Qinghai and Inner Mongolia. This has opened up a potentially prosperous future for PV power generation. Moreover, PV's credentials as an environmentally friendly and fuel saving energy source are being encouraged by the government. Several large companies have entered the market successfully and China has now almost achieved a world class level in technical PV system integration.

4.3.8 Status of PV product exports

In 2006, of the 370 MWp of solar PV cell modules produced, only 10 MWp was consumed domestically, with the rest exported.

up to 2003, the main export products have been solar lamps and calculators. The former includes lawn lamps, yard lamps, street lamps and signal lamps for highways. The main manufacturers are located in guangdong and Zhejiang regions, including the Shenzhen Jiawei and Shenzhen xianxing companies. Their annual turnover is about one billion yuan. Recently, more and more companies are obtaining international certification and entering the world market.

4.3.9 Status of thin film solar cell industry

There are currently three types of thin film solar cells - silicon thin film solar cells, compound thin film solar cells and dye-sensitized photoelectrochemical cells. Silicon thin film is further sub-divided into amorphous silicon thin film, microcrystalline silicon thin film and polycrystalline silicon thin film.

At present, thin film cells take a small percentage of the total world cell production market; however, they represent the clear route forward to high-efficiency cells. The application of multi-films and multi-p-n junction structure film cells would enable a solar-electric conversion rate of 40%-50%. According to the Fhg-ISE theory, a thin film cell with five p-n junctions could achieve a theoretical efficiency of 57%. Among all the types of thin film cells, silicon cells have the unique properties of abundant raw material availability and a non-poisonous, non-polluting lifecycle which encourages sustainable development.

Since the 1980s, when research was conducted into amorphous silicon materials and solar cells, R&D has attached great importance to the potential for thin film.

China's Solar Valley: Baoding

China-Baoding Tianwei yingli new Energy Resources Co. ltd, located in the City of Baoding, designs, manufactures and sells PV modules, and designs, assembles, sells and installs both grid-connnected and stand-alone PV systems. yingli is one of the largest manufacturers of PV products in China, as measured by production capacity, with an annual capacity of 200 MWp of polysilicon ingots and wafers, 200 MWp of PV cells and 200 MWp of PV modules (as of July 2007). The company has a sales income of 2,000,000,000 yuan and a profit of 320,000,000 yuan.

In June 2007 yingli completed an initial public offering on the new york Stock Exchange. It is currently undergoing a new phase of expansion, with the plan to increase its capacity to 400 MWp by 2008 and 600 MWp by 2010. yingli has completed various large projects in Europe and China over the past few years, including the China national Brightness Project in 2002. It cooperated with Solar-Energiedach gmbh n l in the design and installation of a 1 MWp PV system covering the roof of the Kaiseslautern soccer stadium in germany, one of the 2006 FIFA World Cup venues. At the end of 2006, yingli signed a 42 MWp contract with Acciona Energy to help build the world's largest solar plant in Moah, Portugal.

5 Development Potential of PV Power Generation in China

5.1 Solar Resource in China

China is rich in solar resource. In the period 1971-2000, total radiation ranges from 1050-2450 kWh/m^2; area with the radiation of over 1050 kWh/m^2 accounts for more than 96%. Total radiation received on land is equal to 1.7 trillion tons of coal. ①

FIguRE 15 SOlAR EnERgy RESOuRCE DISTRIBuTIOn In ChInA

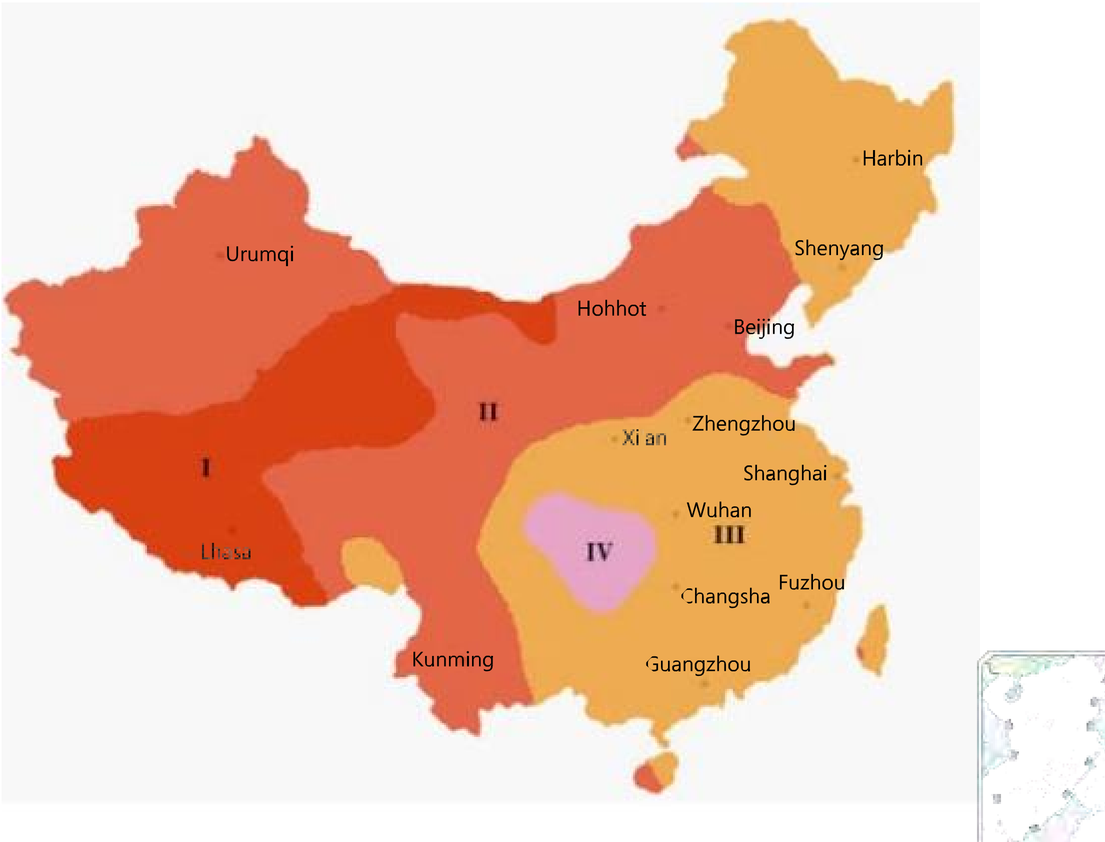


TABlE 14 SOlAR EnERgy RESOuRCE DISTRIBuTIOn ZOnES In ChInA

Colour	Zone	Annual solar radiation /kWh/m²	Share of the national total / %	Area
Most abundant	I	**≥1,750**	17.4	Tibet, south Xinjiang, Qinghai, Gansu, and West Inner Mongolia
Very abundant	II	1,400~1,750	42.7	North Xinjiang, Northeast China, East Inner Mongolia, Huabei, North Jiangsu, Huangtu Plateau, East Qinghai and Gansu, West Sichuan, Hengduan Mountain, Fujian, South Guangdong, and Hainan
Abundant	III	1,050~1,400	36.3	Hill areas in Southeast, Hanshui river basin, West Guangxi
normal	IV	<1,050	3.6	Sichuan and Guizhou

note: Zones I, II and III account for more than 96% of the total.

① Li Junfeng, Review on China's Solar PV Market, Chinese Environment Press, 1999.

China is rich in solar energy resource. The average daily radiation in most areas exceeds 4 kWh/m^2 and is 7 kWh/m^2 at the highest areas of Tibet. Compared with other countries at the same latitude, China has a similar solar energy resource to the uS and much better than Japan and Europe. As shown in Table 14, Zones 1, 2 and 3 cover two thirds of the total area of the country, with an annual solar radiation above 5,000 MJ/m^2 and sunlight time of over 2,000 hours. In Zones 1 and 2 especially, which include remote areas of north-west China with poor transportation, there are not many inhabitants, well spread out, and with a subsistence economy. Their rich solar energy resources can therefore be fully utilised to generate power to develop the local economy and improve living standards.

5.2 Potential Capacity of China's PV Power Market and Rural Electrification

5.2.1 Rural electrification

By 2005, there were 2.7 million Chinese households (about 11 million Chinese people) who did not have access to electricity. Electricity supply for 2 million of these households would be solved through grid extension, small hydro and migration. The rest of 700,000 households would be supplied with electricity through solar PV and PV-wind hybrid systems. given the poverty line (200W/household, and annual electricity consumption of 200 kW. h/household), it is forecast that the installed capacity would be 140 MWp with an investment of 10 billion RMB. given the standard of cities in remote areas (annual electricity consumption of 1000 kW. h/household), then the installed capacity could reach 700MWp.

Township Electrification Programme

In 2002 nDRC launched a project to make electricity available in the countryside. By the end of 2005, 721 sets of wind- solar PV power stations had been completed in West China, providing electricity to 300,000 households, or 1,300,000 people. The investment required was 1,600,000,000 yuan to provide an installed capacity of 15,537 kWp.

The project is the world's largest rural electrification project using solar PV and wind-solar combined, and has so far operated well. nDRC is now organising discussion of follow- up measures to maintain its long-term operation, and to clarify and implement management methods and electricity pricing mechanisms.

By providing an electricity service to rural areas, the programme promotes local economic development and improves living conditions, as well as helping to protect the local and global environment. It also has positive impacts on the PV industry in China by boosting both expertise and capacity building. It has helped build up the solar industry's development.

5.2.2 On-grid PV systems in Buildings

At present about 60% of the solar cells in the world are used in grid-connected power systems, mainly on-grid PV systems in cities. In China, such technology is still at a relatively early stage. It is expected that the building of rooftop projects will start in China before 2010, and the installed capacity will reach 50 MWp by then. It is also expected that there will be on-grid PV projects on a larger scale before 2020, and the cumulative total installed capacity will by then reach 700 MWp. It is forecast that the market share for the system will be 21% of the total domestic PV market by 2010 and 39% by 2020.

The current floor area of buildings in China is about 40,000 million m^2, and the area of building rooftops is about 4,000 million m^2. When south-facing facades are also included, the area increases to 5,000 million m^2. If 20% of this area can be used for solar cells, the installed capacity would be 100 gWp.

Several cities and businesses have started trials of on-grid PV system in buildings. The city of Shenzhen (see box) has completed the largest grid-connected solar PV system in Asia, with an installed capacity of 1 MWp. Other cities, including Shanghai, Beijing, nanjing, Wuxi, Baoding and Dezhou, have also initiated on-grid PV projects.

under the Renewable Energy law, the initial capital investment in on-grid PV systems has to be paid for by the developers. The power is then sold to electricity companies. A feed-in tariff price is determined according to the principle of "costs plus reasonable profits". To accomplish the target, appropriate feed-in tariff policies are vital. Only if such policies are properly carried out will the barrier of the high cost of on-grid PV system be effectively eliminated and the market enlarged further.

grid-connected system in Flower Exhibition Park, Shenzhen

This 1 MWp power station was financed jointly by the Shenzhen local government and Beijing Kenuoweiye Company. It was completed in August 2004 for a total investment of 66,000,000 yuan. This was the first grid-connected solar PV power station in China, and the biggest in Asia at that time. It was a milestone for Chinese solar PV.

The power station is integrated into the building and connected directly to the transmission grid. The total installed capacity of 1,000.322 kWp can generate 1,000,000 kWh of electricity annually, which is equal to the electricity produced by 384 tonnes of coal. It annually avoids the emission of 4.8 tonnes of dust, 101 tonnes of waste, 170 tonnes of carbon dioxide and 7.68 tonnes of SO_2. With the solar PV power station, the Park saves an annual 666,400 yuan on its electricity bill. Over its lifetime of 20 years, the power station could generate 19,600,000 kWh of electricity, avoiding the expenditure of 13,330,000 yuan.

5.2.3 large-scale PV (lS-PV) desert power plants

The biggest potential solar PV market is large-scale desert power plants in the desert. The area of desert, desertified land and potentially desertified land in China amounts to 2,500,000 km^2, accounting for a quarter of the total land mass. using current technology, 1% of this could be used to install 2,500 gWp of solar power plants, generating 3,000 TWh of electricity annually, equal to the current annual output in China.

Based on the current potential and policy in China, it is feasible to develop a demonstration lS-PV power station before 2010. The selection of a desert area should be based on the following criteria: the area is not too far away from the main grid (within 50 km) in order to reduce the need for new transmission lines; the main grid has sufficient capacity to transmit the power from the lS-PV power station without reconstruction; it is not too far away from a power demand centre (within 100 km) so as to reduce transmission loss; and if there is no power load centre nearby, there should be large scale hydro-power capacity so as to consume the power from the lS-PV powerstation for pumped storage.

According to the Mid-long Term Development Plan of Renewable Energy of the national Development & Reform Commission (nDRC), it is expected that there will be three to five desert power plants with an installed capacity of 1-10 MWp operating before 2010, with a total capacity of 20 MWp, in order to test the technology and its economic feasibility. lS-PV desert power plants will be further promoted from 2010-2020, and by 2020 the cumulative total installed capacity in the desert is estimated to be 200 MWp.

Most of the desertified areas are located in the north-west part of China, with an abundant solar energy resource. The annual total radiation is over 1,600 kW.h/m^2. In some north-west deserts, the anuual radiation even reaches more than 2,300 kWh/m^2, which is considered to be the richest solar resource in the world. The desert provides indefinite development space for PV power generation, which needs little water. Many desert areas are near to transmission lines and power load centres which have excellent potential for tourism. It is suggested that these areas should be utilised as the starting point for lS-PV powerstations.

With the development of electricity transmission and power storage technologies, large areas of desert will definitely become the future power base. If only 1% of the desert area is used to install solar cells, the total capacity would be 1,000 gWP, which is about twice the current installed power capacity in China. lS-PV power generation would enjoy the same grid tariff policy as on-grid PV system in buildings. Terrestrial grid-connected PV power plants therefore have brilliant prospects in China.

Desert powerstation, yangbajing, Tibet

The grid-connected solar PV power station in the desert at yangbajing, Tibet was completed in August 2005. With an installed capacity of 100 kWp this is the highest grid-connected PV powerstation in the world and is also China's first PV power station to be connected directly to the high voltage transmission grid. It marked the establishement of a renewable energy centre in Tibet which will carry out research into inverters and safety control technology. It will also provide technical support to renewable energy developmentin China.

5.3 Development potential of other PV markets

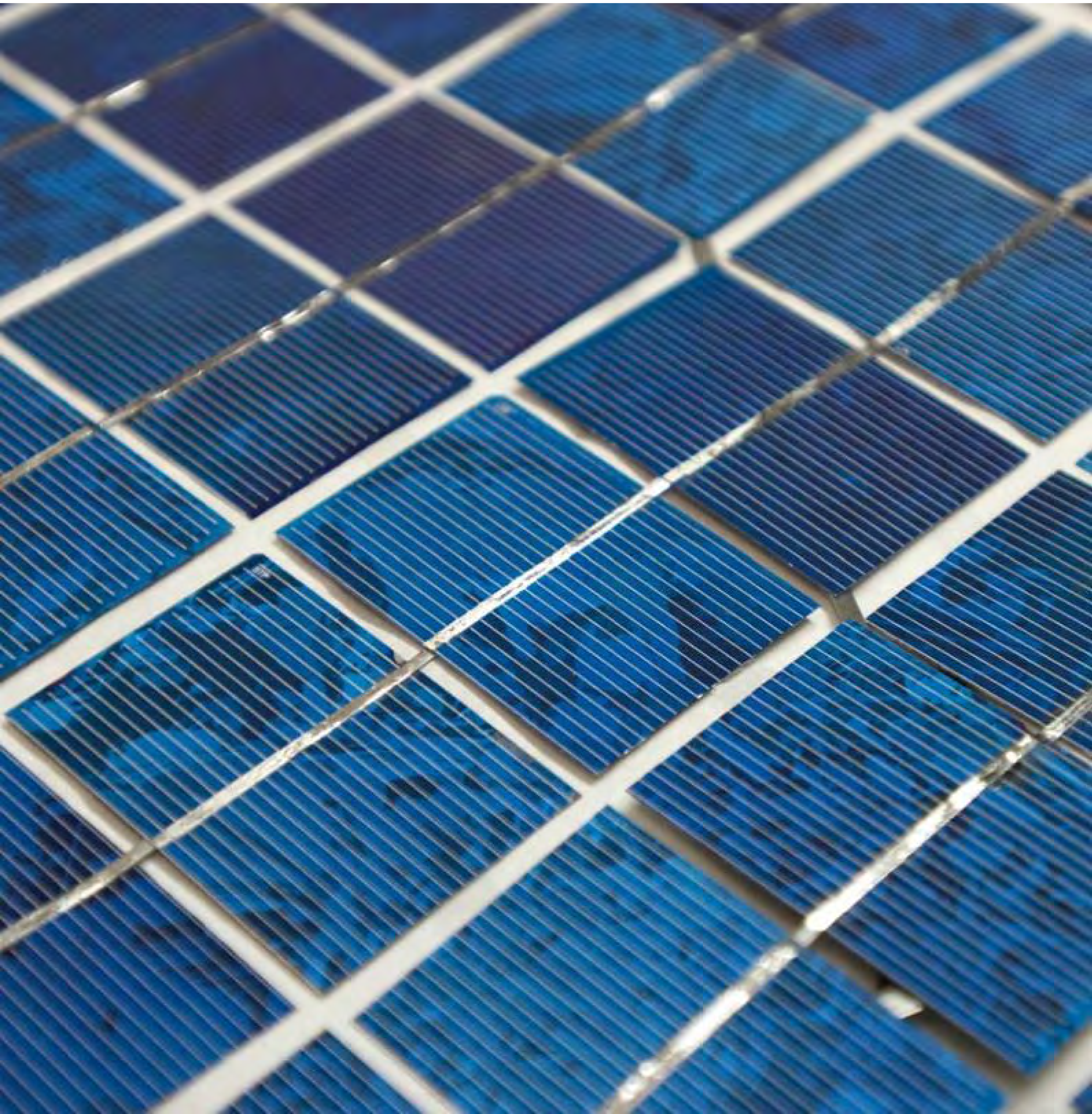
The commercial use of PV refers to those uses of PV without subsidies from the government, including telecommunications, industrial uses and solar PV products. By the end of 2006, this category of solar PV use had reached a cumulative installed capacity of 43 MWp, accounting for 53.8% of the total cumulative installed capacity.

There has been steady demand for telecoms and industrial uses of solar PV; in the most recent two years this has shown an increasing trend. It is estimated that the annual installed capacity in this category will reach about 5-10 MWp by 2010 and 15-20 MWp between 2010 and 2020. Total cumulative installed capacity should reach 300 MWp by the end of 2020.

Solar appliance production is a mainstay of Chinese industry, including solar street lamps, lawn lamps, signal power, solar powered vehicles, solar powered yachts, solar toys, indication boards with IED, advertising boards, transportation signals and city cameras. It is estimated that there are no less than 200 businesses involved in this area. By 2010 domestic demand will be 5-10 MWp and will increase during the period 2010-2020, reaching a cumulative installed capacity by the end of 2020 of 200 MWp.

As a result of technology improvement and market development, appliances in new areas and new products will develop rapidly. The fast development of the international solar PV market will also encourage production in China. The cumulative installed capacity of the commercial PV market is expected to reach 500 MWp by 2020, with an annual production of 30-50 MWp.

6 Analysis of PV Power Generation Costs



6.1 Cost analysis of crystalline solar cells

Over 60% of the total cost of supplying electricity from solar PV comes from the solar cells. Their current high price has resulted from a shortage of silicon, temporarily distorting the market. According to the expected normal development pattern, solar electricity will be able to compete with conventional sources within ten years. Since 80% of the solar market is crystalline solar cells, we have concentrated here on analyzing costs for this type of cell.

In 2006 the price of solar modules fell from $4.05/Wp to $3.60/Wp in the international market, compared to the year before. In China, the current price for modules is 32 yuan/Wp. This compares with the price in the first half of 2005, which was as high as 38 yuan/Wp①.

The costs for the various stages of the manufacturing process are as follows:

- Polycrystalline Silicon: Market purchase price is $200-250/kg ($50-60/kg for large and long contract purchases). Assuming the price is $220/kg, and 9.3g silicon material will make a 1 Wp solar cell, then 1 kg silicon material could make 107.5 Wp solar cells, resulting in $2.05/Wp ($0.47-0.56/Wp for large and long contract purchases).
- Solar Wafers (after casting or cutting): $6.0/piece sized 125*125, 2.4Wp/wafer, resulting in $2.5/Wp
- Solar Cells: $3.0-3.1/Wp
- Solar Modules: $3.6-3.7/Wp

Figure 16 shows that the cost of polysilicon material represents the biggest proportion (56.2%) of the total cost, and therefore has the biggest impact. The current high price of solar modules is caused by the shortage of polysilicon material. If a sufficient supply of polysilicon material is resumed, and the price drops to $50-60/kg ($0.55/Wp), the price of solar modules could fall to $2.2-2.5/Wp. A reasonable system price is below $5/Wp.

FIgURE 16 PERCENTAGE COST OF EACH STAGE IN THE MANUFACTURING PROCESS

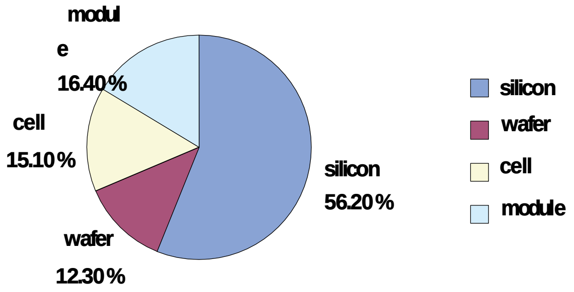


TABlE 15 PRICES FOR MANUFACTURING PROCESSES AND VALUE ADDED IN 2007

Process	Polycrystalline silicon	Wafers	Cells	Modules
Sales price /$/Wp	2.05	2.5	3.05	3.65
Value added /$/Wp		0.45	0.55	0.60
Percentage of total cost / %	56.16	12.33	15.07	16.44

① Wang Sicheng etc., Research on China's PV Technology and Industrial Development, July 2007.

6.2 Deciding factors of electricity price

The influential factors of electric price are initial investment, electricity generation, lifetime, financial fees and operation costs.

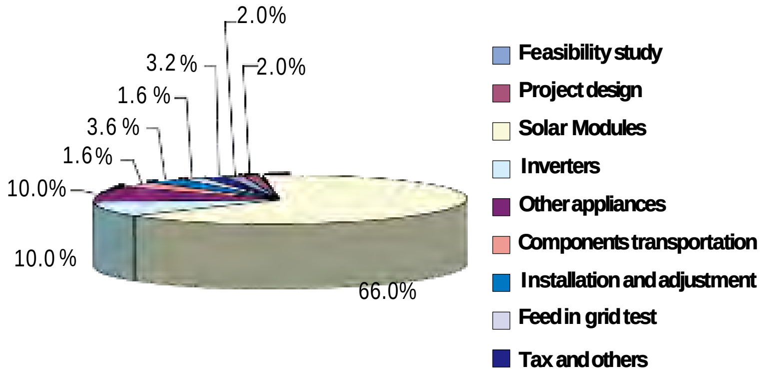
6.2.1 Initial investment

In 2006, the initial investment for a PV system was around 50,000 yuan /kWp.

TABIE 16 InITIAl InVESTMEnT FOR 1 KW gRID-COnnECTED SOIAR PV

Component/process	Investment / 10^4 yuan	Percentage / %
Feasibility Study	0.10	2.0
Project design	0.10	2.0
Solar modules (including mounts)	3.30	66.0
Inverters	0.50	10.0
Transformer, power monitoring and cables	0.50	10.0
Component transportation	0.08	1.6
Installation adjustment	0.18	3.6
Feed in grid test	0.08	1.6
Tax and other costs	0.16	3.2
Total	5.00	100

FIguRE 17 COST BREAKDOWn OF gRID-COnnECTED PV SySTEM



6.2.2 Estimated Power Output of Different PV Systems

The operating efficiency of different systems can be assessed as follows:

1) System efficiency

- Stand alone PV systems can be installed at the correct angle, facing south, so the system efficiency is about 68% (battery efficiency 95%, voltage coefficient 85%, inverter efficiency 90% and other efficiencies 94%). The investment cost in 2006 was 70,000 yuan/kWp, decreasing by 7% annually.
- On-grid PV system is limited by the installation angle so system efficiency is about 74% (inverter 95%, loss due to the incorrect angle 15%, other efficiencies 92%). The investment cost in 2006 was about 50,000 yuan/kWp, decreasing by 15% annually.
- IS-PV can avoid losses from an incorrect angle, but a transformer is needed and the desert area is dustier than in towns. System efficiency is about 80% (inverter 95%, transformer 95% and others 89%). The investment cost in 2006 was about 50,000 yuan/kWp, decreasing by 7% annually.

3) Average annual usable hours for different PV systems

Analysis of the annual usable hours in the 26 provinces, autonomous regions and municipalities directly administered by China's central government shows the following results (not including the four regions with the worst solar resource).

2) Solar resources and annual usable hours

TABIE 17 uSABIE hOuRS In DIFFEREnT AREAS OF ChInA

Area	Annual sunshine hours	Daily sunshine hours
north west (9 provinces)	1,828.4	5.01
East (17 provinces)	1,496.4	4.10
Central and south (4 provinces)	1,204.5	3.30
Average	1,557.1	4.27

TABIE 18 nATIOnAl AVERAgE OF uSABIE hOuRS FOR DIFFEREnT PV SySTEMS

Contents	Annual usable hours for Stand Alone PV Stations	Annual usable hours for BIPB	Annual usable hours for IS-PV
Annual Maximum	1,668.3	1,815.5	1,962.7
Annual Minimum	896.5	975.6	1,054.7
Annual Average	1,095.7	1,192.4	1,289.1

Note: Annual usable hours = annual sunshine hours x system efficiency

According to the above table, the national average of efficiently usable annual hours for different systems are:

Stand Alone PV Stations: 1,100 hours

On-grid PV system in Buildings: 1,200 hours

IS-PV: 1,300 hours

6.2.3 Estimates of operation and maintenance costs

Operating and maintenance costs include repair costs, depreciation, salaries and benefits and other miscellaneous costs.

Annual operation and maintenance costs

Operation and maintenance costs=fixed asset investment*the rate of operation and maintenance.

The PV station doesn't consume fuel and a grid-connected system is not complicated. Moreover, we can assume that the operation and maintenance rate is 0.2%. An IS-PV is similar, with an assumed rate of 0.2%.

Annual salary and welfare, insurance and other operational costs

A grid-connected system only needs part-time management. This is assumed to represent 0.8% of the initial investment. The work demanded by an IS-PV grid-connected PV system is also comparatively low, but it still needs management by specialists. This is assumed to represent 0.8% of the initial cost.

Repairs and overhaul

Solar cells can last for 20-30 years, so they do not need to be replaced during their lifetime. A grid-connected PV power system doesn't involve a storage battery, but the inverter needs to be replaced once during its life. Replacement cost is the same as for the initial inverter, which accounts for 8% -10% of the total investment.

Depreciation

Depreciation is the original value of the fixed asset multiplied by the depreciation rate. 80% of the initial investment is assumed to be the fixed asset and the depreciation period is 20 years, with an annual depreciation rate of 5%. Depreciation of the fixed asset is subtracted and used as a write-off against the loan's compound interest.

6.2.4 Fiscal costs

It is assumed that 70% of the initial cost is through a loan, the rest is self-financed. loan interest over a period of 20 years has to be financed at an annual interest rate of 6.12%. Return on capital is assumed to be 10% per year.

6.2.5 Tax

Income tax is not payable. Value added tax is paid at a rate of 6%. urban construction tax is 5% of the value added tax and additional tax for education is 3%of the value added tax.

6. Factors affecting PV cost reductions

- Technological innovations and improvements
- Increasing the performance ratio of PV
- Extension of PV systems' lifetime
- Economies of scale

6.3 Estimate and forward projection of solar electric costs

The cost of generating solar electricity is calculated as follows:

Electricity tariff (yuan/kWh) = (annual capital benefit + annual loan payback + average annual interest + depreciation
+ annual operation cost) / electric generated.

According to international estimates, the initial investment will decrease at an annual rate of 10%. Table 19 shows the current cost for solar electricity and future projections up to 2020.

TABIE 19 gRID-COnnECTED EIECTRICITy COST ESTIMATES

Cost element	2006	2010	2015	2020
Initial investment per kWp	50,000	32,805	19,371	11,438
Self-funding (30%)	15,000	9,842	5,811	3,432
loan (70%)	35,000	22,964	13,560	8,007
loan payback	1,750	1,148	678	400
loan interest (20 year average)	1,125	738	436	257
Depreciation (20 years)	2,000	1,312	775	458
Compensation for loan and interest	-2,000	-1,312	-775	-458
Operation and maintenance (1%)	500	328	194	114
System replacement (0.5%)	250	164	97	57
Capital benefits (10%)	1,500	984	581	343
Eletricity cost including tax and benefits (yuan/kWh)	5,480	3,595	2,123	1,254
Eletricity cost including tax and benefits (yuan/kWh)				
1,000 hours	5.5	3.6	2.1	1.3
1,100 hours	5.0	3.3	1.9	1.1
1,200 hours	4.6	3.0	1.8	1.0
1,300 hours	4.2	2.8	1.6	1.0
1,400 hours	3.9	2.6	1.5	0.9
1,500 hours	3.7	2.4	1.4	0.8

6.4 Comparison with conventional electricity costs

China's conventional electricity prices are currently very low,[①] but expected to rise over the next 14 years. The increasing trend is shown in Table 20. Together with an anticipated rise in the PV payment tariff, it is expected that PV electricity will be able to compete with conventional power by around 2030.

however, it should be pointed out that the price for conventional electricity does not reflect the actual production costs. In China, coal has been variously subsidized for many years. unless financial support for renewable energy sources such as PV is offered on a similar basis, such a comparison is unfair.

The external costs to society resulting from burning fossil fuels are also not included in current electricity prices. These costs have both a local and a global component; the former refers to air pollution such as acid rain and dust, the latter relates to the consequences of climate change. There is uncertainty, however, about the magnitude of such costs, and they are difficult to identify.

TABIE 20 TARIFF FOR COnVEnTIOnAI EIECTRICITy

year	2006	2010	2015	2020
Average electricity tariff (yuan/kWh)	0.310	0.349	0.404	0.469
Annual increase rate	3%			

① Wang Wenjing, Wang Sicheng, etc., *Estimation of Classified PV Electric Price*, WWF research report, 2005.

7 International Experience of Solar PV Policies

7.1 Foreign experience

According to *Energy Revolution* solar PV will be able to generate 1.6% of total global electricity by 2020, 8.1% by 2040 (depending on overall electricity consumption), and 10.9% after 2050.[①] Europe is the leader and driving force in renewable energy development, with an annual growth rate of over 2% both in the renewable energy market and in the industry.

The relevant policies adopted in germany, the united States and Japan, that is, national roadmap, pricing policy, financial subsidy, tax credit, loan subsidy, and exportation encouragement, have helped to make them leaders in PV development worldwide.

7.1.1 germany

Many European countries, such as germany and Spain, have adopted a feed-in-tariff for the payment of renewable energy generators. The german Renewable Energy law stipulates that the main transmission grid companies (utilities) must purchase the output from renewable energy generating stations at a premium price set by the government. grid companies are obliged to purchase all the electricity generated by renewable energy and pay the minimum grid compensation tariff, which is a fixed price over a specific time period. For PV this is 20 years plus the installation period. The electricity price for a newly built power plant is then subject to a gradual percentage reduction. For PV this is a 5% reduction each year. The extra cost of supporting renewable energy compared to the price paid to conventional generators is shared across all electricity consumers.

In germany the price paid varies according to the type of renewable energy. This is intended to reflect their relative level of technology development, thus encouraging a range of renewable technologies to reach commercial utilization. For PV power generation the price is 37.97~54.21 Euro cents/kWh. A similar mechanism is now operating in almost 40 other countries. In addition, the german bank KFW has set up a special fund for renewable energy investment which aims to facilitate the finance of renewable energy projects.

- The main feature of the Renewable Energy law introduced in 2000 in germany is the feed-in-tariff. Parts of the law which relate to PV are:
- Public utilities are obliged to purchase all the grid-connected electricity generated by PV at a price of 50.6 Euro cents/kWh
- The fixed price is effective for 20 years
- There is a gradual percentage reduction for newly built powerplants (PV = 5 %/a)
- The additional cost of the tariff is shared by the four transmission grid companies across all electricity consumers.

The german Renewable Energy law was revised in 2004, with a differentiation made for different types of PV power generation, as shown in Table 21.

TABlE 21 gERMAn gRID-COnnECTED PV TARRIF In 2007

grid-connected systems	Electricity price / Euro cents / kWh		
2004	First 30 kWp	30 to 100 kWp	Above 100 kWp
Buildings/sound barriers	49.21	46.82	46.30
South vertical surface of building	+ 5		
IS-PV in rural area	37.96		

① Greenpeace/EWEC, Energy Revolution, 2007.

The accompanying regulations for the Renewable Energy law allow its provisions to be combined with a low interest loan. loan support from the kW bank for a PV installation is as follows:

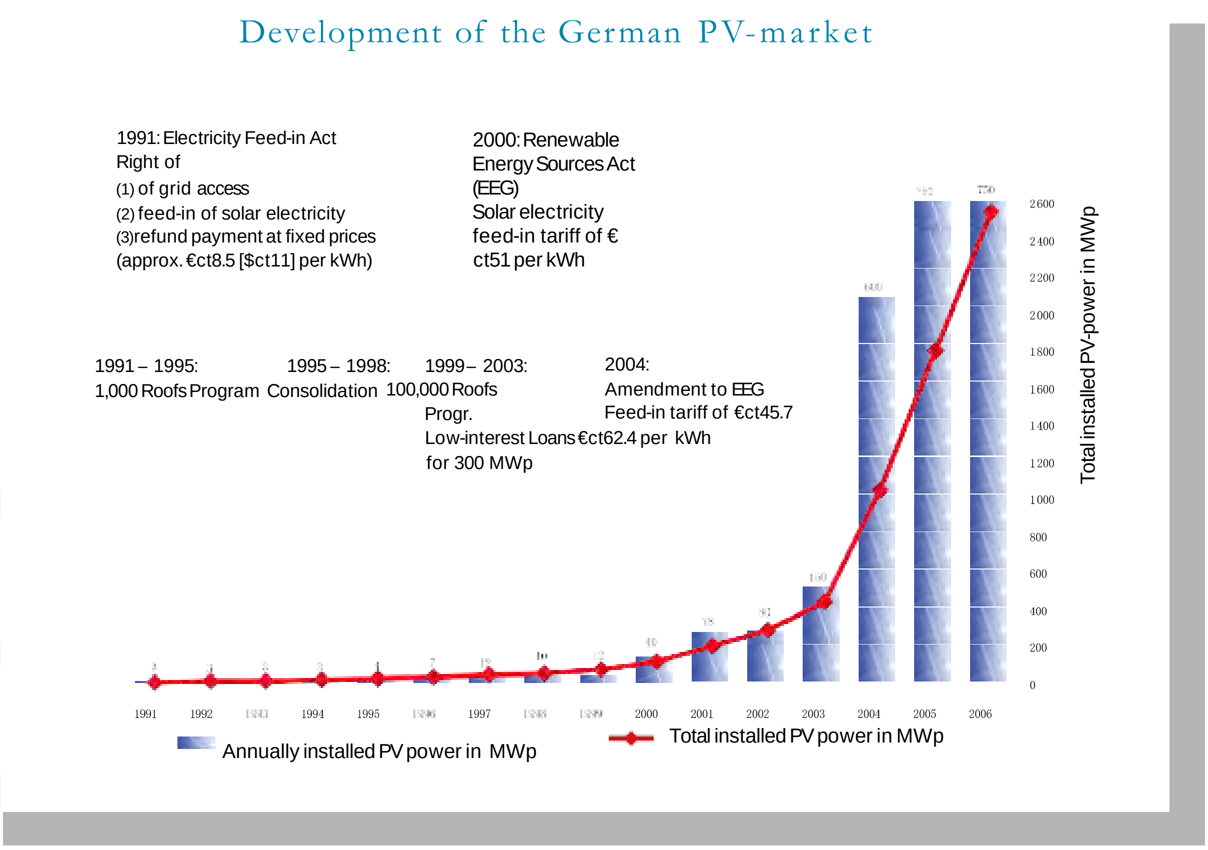
- long-term low interest loan subsidised by the government
- loan period of 10, 12, 15, 20 or even 30 years and with no repayments necessary for the first 2, 3 or 5 years
- Fixed interest rate for at least 10 years

It is calculated that on average each german household only spends about 2.4 Euros annually to cover the extra cost of the feed-in law for solar PV installations. The result is that the so-called "100,000 PV Roof Plan" has been successfully implemented by the german government. The success of the german law can therefore be summarized as:

- PV power generation is successfully encouraged without direct financial investment from the government.
- The project developer gains considerable benefit from the sale of electricity.
- A large quantity of PV systems have been installed, exceeding the planned annual installation rate of 300 MWp within five years.
- Total installed capacity in germany has reached 2,530 MWp (end 2006), with an annual market volume in 2006 of approximately 750 MWp.
- PV businesses profit from the sale of electricity, developing the PV industry.
- The annual price adjustment encourages PV development along market lines.
- The bank loan is paid back.
- Approximately 20,000 jobs have been created in the photovoltaics industry.

Although the 100,000 PV Roof Plan ended in 2003, the solar PV boom in germany has continued.[①]

FIGURE 18 PV INSTALLED CAPACITY FROM 1990 TO 2004 IN GERMANY



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① Wang Sicheng etc., Report of the European Solar PV Market, 2006.

7.1.2 united States

In the united States, The Department of Energy has announced ambitious plans and development paths for renewable energies, including wind, solar and biomass, in order to increase the share of clean energy. Solar PV power generation is forecast to account for 15% of total increased capacity by 2020, which would be 20 gWp. The uS is expected to continue to take a leading role in technology development as well as PV manufacturing capacity.①

Thirty states in the uS have passed net metering laws, which allow PV power generation to feed into the grid and then only to be charged for the net amount consumed (the meter can be reversed). When electricity use is more than electricity generated by the PV system, the user pays the difference. The "Buy Down" policy implemented in California enables direct subsidy towards the initial investment in solar PV power systems, with a payment of 4 uS$ / peak watt.

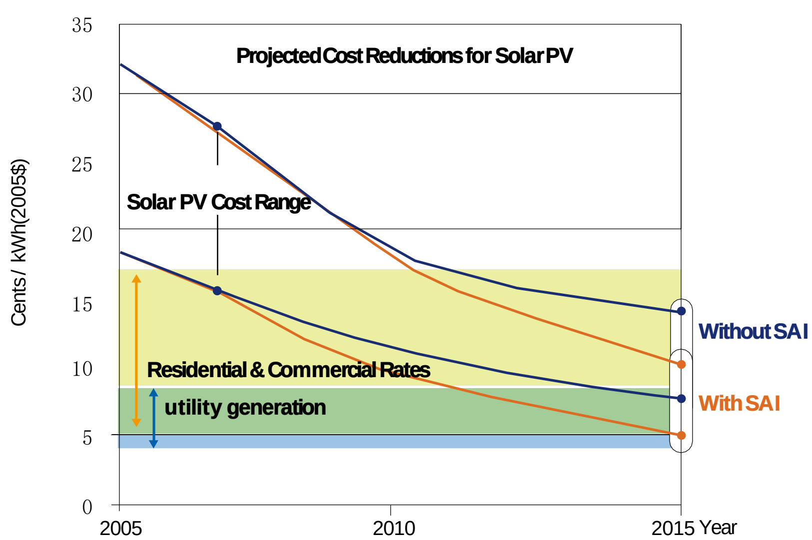
In February 2007 the Department of Energy issued the SAI (Solar America Initiative) 2006-2010 plan, the main features of which are:

- Special support to manufacturing processes, products and research projects that could reduce costs, improve efficiency and PV reliability.
- Investment in R&D projects targeted at reducing PV industry to costs and enlarging production.
- Support for new solar cell companies that have the potential to transfer from the laboratory to the commercial stage. With investment from Department of Energy, technical support from nREI (national Renewable Energy laboratory) and Sandia national laboratory, the new generation of solar cells will be put on the market after 2011.
- Support for the elimination of non-technical barriers, including technical standards, technical specification, product certification and technical training.
- Facilitating the establishment of partnerships between power companies in the same state to jointly stipulate regulations and incentive policies and to accelerate the promotion of solar energy use.
- Support for the technology development of solar thermal power.
- In 2007, the total solar R&D budget is $148.7 million, of which $139.8 million is allocated to PV, with $8.9 million to be spent on concentrating solar thermal power generation.

The federal government of the uS has not passed a specific law promoting renewable energy. however, more than 20 state governments have passed laws which stimulate the implementation of renewable energy.

In terms of the power price, some uS states have adopted the avoided cost calculation method. The avoidable costs are compared to those of conventional energy, therefore different renewable technologies receive a different price. Other states have adopted the net metering measure, which sets the renewable energy power price on the basis of the sale price to consumers. This price mechanism is similar to the fixed price

FIguRE 19 PV POWER COST TARgET WITh SAI SuPPORT



① Li Junfeng etc., Report of American Renewable Energy Development, 2006.

feed-in- tariff and has a similar effect.

Some states have implemented a quota or trading system. The quota system requires energy companies to produce and sell a certain percentage of renewable electricity. The trading system refers to green Certificates, which are issued to renewable energy power producers and can then be traded, with the price determined by the market. This fully utilizes the concept of market self-regulation and improves the price of renewable energy because the price is the sum of the average grid electricity price plus that of the green Certificate. under this system, the government stipulates the financial penalty for those companies that fail to achieve their quota, which usually becomes the level of renewable energy power transactions.

7.1.3 Japan

Japan started implementation of the "new Sunshine Project" in 1993, with the aim of accelerating the development and utilization of PV cells, fuel cells, hydrogen and geothermal energy.① The PV target for 2010 is 4.8 gWp. In 1997, the "70,000 Solar PV Roof Plan" was announced, aiming to install solar cells with a capacity of 7.6 gWp by 2010. Figure 20 shows the target (red dotted line) under the new Sunshine Project and the actual implementation status (brown solid line). This shows that programme is ahead of schedule. South Korea plans to implement a similar "Million Roof Plan", with the aim of becoming the third largest country for solar PV.

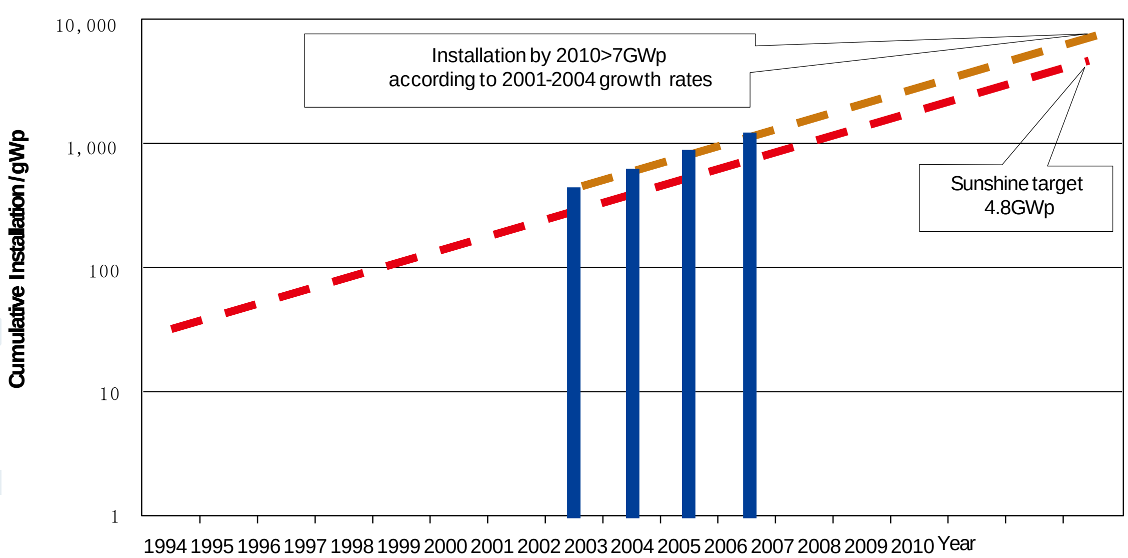
With government policy support, solar PV technologies started to boom in Japan from 1990 onwards and have maintained a steady growth. By 2006, the annual production capacity of solar cells by Sharp and Kyocera, listed as no.1 and no.3 in the world, amounted to a total of 614 MWp.

In Japan, a user subsidy policy has been implemented, which means that a subsidy is paid towards the capital cost of installing a PV system.② This subsidy is subject to change according to the level of market development and technical improvement. There is also an annual reduction from the original 50% subsidy to zero over ten years. In 2005, however, the subsidy for rooftop PV power systems was cancelled. In addition to the subsidy system, PV power is allowed to feed into the grid on the basis that the power company purchases the power generated at the same electricity price as paid by the consumer, a situation similar to net metering in the uS. As the conventional electricity price in Japan can be as high as 2.4 yuan/kWh, rooftop enjoys a large market, even without subsidy for the initial investment.

PV roadmap of Japan also shows that the system cost of grid-connected PV will decrease from 44,000 yuan/KWp in 2005 to 20,000 yuan/KWp in 2020. By 2020, the PV electricity price will be 0.93 yuan/KWh; by 2030, it will be 0.47 yuan/KWh. Such price could be quite competitive with conventional electricity.

The progress that has been made in the field of PV in germany, the uS and Japan would not have been possible without government support in terms of targets, price incentives, fiscal subsidy, favourable taxes, loan support, export encouragement, scientific research and industrialisation.

FIgURE 20 TARgET AnD ACTuAl IMPlEMEnTATIOn OF JAPAn'S nEW SunShInE PlAn



① Kazuo Yoshino, The Case of Photovoltaic Development in Japan, 2005.

② Li Junfeng and Ma Linjuan etc., Report of Solar PV Industry Development, 2007.

7.2 Forecasts for World Solar PV Development

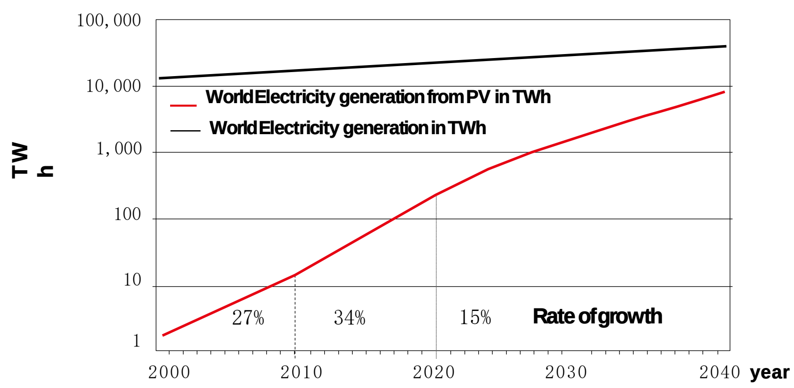
7.2.1 IEA Forecast

The International Energy Agency (IEA) has made an estimate of the future development of solar PV power generation. It forecasts that world PV power generation will account for 1% of total electricity generation by 2020 and 20% by 2040, as shown in Figure 21.

7.2.2 JRC Forecast

According to estimates by the European Commission's Joint Research Centre, renewable energy will account for over 30% of the total energy mix in 2030, with solar PV power accounting for over 10%. These figures will increase to 50% and 20% respectively by 2040. By the end of this century, renewable energy will account for over 80% of the energy mix and solar power for over 60%, according to the JRC, indicating its potential strategic role, as shown in Table 22.

FIgURE 21 IEA FORECAST OF SOIAR PV POWER gEnERATIOn



TABIE 22 JRC FORECAST OF FuTuRE EnERgy DEVEIOPMEnT

	Proportion of the energy mix / %	
	2050	2100
Renewable energy	52	86
Solar energy (including solar thermal use)	28	67
Solar power generation (including solar thermal power)	24	64

7.2.3 EPIA Forecast

The European Photovoltaic Industry Association estimates[1] that the world solar PV module industry will reach a production output of 28 gWp by 2020 under its Moderate (M) scenario and 44 gWp under an Advanced (A) scenario. Total PV installed capacity will reach 170 (M) and 240 (A) gWp, with 225 (M) and 320 (A) TWh of electricity generated, accounting for 1 (M) and 2 (A) % of global electricity supply. A PV module will by then cost $1/Wp. By 2040, PV electricity output will reach 6400 TW.h and account for 20 (M) and 28 (A) % of the world total.

In summary, a high level of consistency can be seen between the different estimates for renewable energy development and future PV power generation, evidence of both a scientific consensus and reliability in the projections. These projections show the urgency of replacing fossil fuels with renewable energy and the strategic role that PV power generation can play in the future.

① EPIA/Greenpeace, Solar Generation IV, 2007.

8 Policy and Roadmap for Solar PV Development in China

8.1 Current Policy Framework

The main policy framework for renewable energy in China includes the national development plans and the Renewable Energy law. Development plans for solar PV are contained in both the 11th 5-year-Plan and the Mid-to-long-term Renewable Energy Development Plan. In addition, solar PV is able to make a huge contribution towards poverty alleviation and the universal availability of energy services.

1. Subsidies for PV in Rural Areas

Based on the principle of providing universal energy services, the Chinese government subsidies the development of solar PV in remote rural areas in order to secure an electricity supply. The subsidies take the form of project subsidies, user subsidies and construction assistance. The funding mainly comes from the central government budget, local government budget and international aid. Over the past ten years, the Chinese government has introduced many such initiatives, including:

- From 1996 to 2000, more than ten solar PV power systems were built in Tibet to provide electricity for villages without access to the grid. The power produced by PV covered lighting and other basic residential electricity uses.
- In 1997, the government introduced the "Bright Project", which started with pilot projects in Qinghai, xinjiang, Inner Mongolia and other provinces. This initiative supported the use of solar PV to provide domestic electricity for peasants and herdsmen. Funding came from international aid and the local government budget. The project distributed solar PV devices to schools, hospitals and local people.
- With the help of the global Environment Fund, the Chinese government implemented the Renewable Energy Development Programme through the World Bank. The Programme was designed mainly to promote household solar PV systems in the nine provinces of Western China, including Inner Mongolia, Tibet, Qinghai, gansu, xinjiang, Shaanxi, yunnan, ningxia and the west part of Sichuan.
- From 2002 to 2004, the Chinese government initiated the Township Electrification Programme, which mainly used solar PV. The Programme received 2 billion RMB from central government and 1 billion from local government. Electricity supply was introduced to over 700 villages, representing more than 200,000 households and about 1 million people.

There have also been many other initiatives by provincial governments to subsidise the use of solar PV for peasants and herdsmen. In xinjiang and Qinghai, for example, every installation of solar PV could receive between 100 and 200 RMB in subsidy.

The above initiatives have helped maintain a domestic market for solar PV and laid down good foundations for future development.

2. R&D Support Schemes

The government has also provided various support schemes for the research and development of solar PV. These include:

- Basic R&D Support Scheme, also known as 973 Scheme

  This supports future solar PV technologies, including backing for the technical and theoretical development of thin-film and dye sensitised solar cells.

- high-tech R&D Support Scheme, also known as 863 Scheme

  This supports solar PV technologies which are about to become commercialised, including basic equipment and materials for solar power, cadmium telluride, copper indium germanium selenium and thin film silicon solar cells.

- Key R&D Support Scheme, changed to Pillar R&D Support Scheme in 2006

  under the 6th 5-year-Plan, the government has made key solar PV technologies part of the Pillar R&D Support Scheme, which has helped lay down the foundations for commercialisation of solar PV in China.

- Commercialisation Support Scheme

This scheme provides funding for the development of solar industries. Among the recipients have been solar PV manufacturers, including Wuxi Suntech, Baoding yingli green Energy, Changzhou Trina Solar and xinjiang new Energy, and silicon manufacturers including Sichuan xinguang Silicon and luoyang Silicon high-Tech.

3. Pilot Projects

Pilot projects are also an important means of promoting solar PV and support the industry technically and financially. More than 1 million household PV systems, more than 1,000 village PV power stations, over 100 grid-connected roof PV systems and one large 100 KWp grid-connected desert power station have been installed. All of these pilot projects have accumulated valuable experience for the development of solar PV in China.

local authorities are encouraged to carry out their own solar PV pilot projects. Solar Road lighting and Solar Roof programmes have been implemented in Shanghai, Beijing, nanjing, Shenzhen and other cities. Mega events such as the Beijing Olympics and the Shanghai Expo also try to promote solar PV by installing it in various venues. Some cities such as Dezhou in Shandong Province and Baoding in hebei Province are trying to build a Solar City. good examples of local initiatives include:

- Shanghai's "100,000 Solar PV Roof Plan": Shanghai plans to build 100,000 Solar PV on roofs in the five years from 2006 to 2010, with an estimated total installed capacity of 400 MWp.
- Beijing's "Solar Road lighting Project": Beijing plans to supply road lighting with solar PV power in rural streets and some main roads using government funding. Solar PV is also being installed in some of the Olympic venues.
- Jiangsu's "Solar PV Promoting Plan": The Jiangsu provincial government plans to install solar PV at some airports and in landmark buildings in various cities.
- Desert PV Station: The Ministry of Science and Technology has arranged specific funding to build four pilot projects of desert PV stations in gansu, Tibet, Sichuan and one other location.

To combine the central government's vision with local government initiative is very helpful for the rapid development of PV technology and the creation of a domestic PV market.

8.1.4 Development Plans and goals

Renewable energy power generation is scheduled to play an important role in the development of energy in China. For the first time, planned targets for electric power generation using renewable energy sources have been included in China's Five-year Plan (2006-2010), as well as in the medium-to-long-term plans. This reflects the commitment of the government to promote and direct these technologies. The expected development of renewable under the plans can be seen in Table 23.①

Table 23 shows that solar PV power generation will play a significant role in China's future energy supply. According to the present plan, total PV power installations will reach 300 MWp by 2010, 1.8 gWp by 2020 and 1,000 gWp by 2050. According to forecasts made by the *Chinese Electric Power Research Institute*, renewable energy installations will account for 30% of total electric power capacity in China by 2050, of which PV installations will account for 5%.

TABlE 23 DEVElOPMEnT PlAn (uP TO 2020) AnD FORECASTS (uP TO 2050) FOR REnEWABlE EnERgy POWER gEnERATIOn In ChInA

Year		2004	2010	2020	2030	2050
Small hydropower	Installed capacity / gW	34	50	75	100	200
	Annual production / TW.h	100	154.5	230	320	640
Wind	Installed capacity / gW	0.76	5	30	100	400
	Annual production / TW.h	1.14	10.5	69	230	920
Biomass	Installed capacity / gW	2	5.5	20	50	100
	Annual production / TW.h	5.18	21.2	83.5	225	500
PV	Installed capacity / gWp	0.065	0.3	1.8	10	100
	Annual production / TW.h	0.078	0.42	2.16	14	150
Percentage of total electricity from renewable energy / %		6.5 (3)	10 (4.2)	16 (8)	20 (14.6)	30 (22.5)

* *note*: using 1 kWh=350 g coal equivalent, large-scale hydropower not included.

① Wang Sichen and Hu Xuehao etc., Study of the Mid-to-long-term Strategic Plan of Chinese Energy Development, 2007.

8.2 2006 Renewable Energy Law

The Renewable Energy law of the People's Republic of China was authorized and established by the Standing Committee of the national People's Congress on February 28, 2005, and has been in effect since January 1, 2006. Articles related to PV power are as follows:

8.2.1 Articles Related to grid-Connected PV Power Systems

Article 14: grid companies shall enter into grid connection agreements with renewable power generation enterprises that have legally obtained an administrative license or for which filing has been made, and buy the grid-connected power produced from renewable energy within the coverage of their power grid, and provide grid-connection services for the generation of power from renewable energy.

Article 19: The grid power price for renewable energy power generation projects shall be determined by the price authorities of the State Council according to the principle of being "beneficial to the development and utilization of renewable energy and being economic and reasonable", and timely adjustment shall be made on the basis of the development of technology for the development and utilisation of renewable energy. The price for grid-connected power shall be publicised.

Article 20: The difference between the cost for power grid enterprises to purchase renewable power on the basis of the price determined in Article 19 and the cost incurred in the purchase of average price power generated by conventional energy shall be included in the selling price. The price authorities of the State Council shall prepare specific mechanisms to give effect to these provisions.

8.2.2 Articles Related to Off-grid PV Power Systems

Article 15: The government supports the construction of independent renewable power systems in areas not covered by the power grid to provide a power service for local industry and households.

Article 22: For power generated from independent renewable energy power systems which the government has invested in or subsidized, the classified selling price of the same area shall be adopted and the excess between the reasonable operational and maintenance expenses and the selling price shall be shared on the basis of the method specified in Article 20.

8.2.3 Implementing Rules for the Renewable Energy law

The national Development and Reform Commission (nDRC) of the People's Republic of China published Provisional Administrative Measures on Pricing and Cost Sharing for Renewable Energy Power generation on January 4, 2006. The articles relevant to PV power generation are as follows:

Article 9: The government fixed price applies to solar, wave and geothermal power generation projects. The price shall be determined by the price authorities of the State Council based on the principle of "reasonable costs plus reasonable profits".

Article 12: The incremental cost of 1) the feed-in tariff for renewable energy power generation over the yardstick feed- in tariff for desulphurised coal-fired power generating units, 2) operational and maintenance costs for state-invested or subsidied central stand-alone power systems from renewable energy over the average electricity sales price of the local provincial grid, and 3) the grid connection costs for renewable energy power generation projects, shall be settled via a tariff surcharge levied on electricity end-users.

4. Difficulties with implementing the Renewable Energy law

From the above law and regulations, we can see that

- Both building-integrated PV systems and large-scale desert PV power plants will be subject to the "feed-in tariff" policy. This means that developers will pay for the initial investment in the power generation system, and will then obtain revenue by selling the electricity generated. Electricity companies are expected to purchase PV-generated electricity at a reasonable feed-in tariff price (reasonable costs plus reasonable profits).
- For off-grid central PV power plants in villages, the initial investment will be paid by the government (household systems are not included), and the portion of the cost of subsequent operation and maintenance that exceeds the revenue from electricity fees (including the cost of renewing the storage batteries) will be apportioned to the nationwide electricity network by increasing the electricity tariff.
- End-users, whether grid-connected or off-grid, will pay for their electricity according to the "same network, same price" principle: in other words, the electricity tariff paid by PV power users will be the same as the electricity tariff paid by grid-connected power users in the same area.

however, there still exist many difficulties in implementing the support policies for solar PV. Firstly, for grid-connected PV, a dozen PV power systems have been installed, with capacities ranging from several kWp up to 1 MWp. however, in no case has a feed-in tariff, calculated according to "reasonable costs plus reasonable profits", been implemented and no PV power system has as yet been permitted by grid companies to connect to the grid. no project has as yet been built by developers for commercial operation.

The Renewable Energy law is proving more difficult to execute for PV than for wind power. Wind power systems have been built by developers to gain profits for many years (without needing investment by the state), power companies have accepted this and have accordingly executed the "tariff" policy.

For off-grid PV, although the Renewable Energy law and regulations have made it clear that the cost should be apportioned across the whole network for the subsequent operation and maintenance of PV plants (more than 720) that were built under the Township Electrification Programme, the transfer of these power plants has not yet been completed. Although the warranty period of three years has expired, maintenance is still being carried out by the constructors (system integration enterprises). The annual maintenance cost is about yuan 4,000 per kWp, and these outlays have not been settled so far. A mechanism needs to be urgently developed to incorporate the renewable electricity tariff into the national electricity network so the accumulated funds can be used for the operation and maintenance of rural PV plants according to the principle of the Renewable Energy law. Otherwise these plants, which were built with an investment of several thousand million yuan, will become redundant. Such a problem will also face the phase of the Township Electrification Program which is about to be implemented.

So far, PV power has not been accepted by grid companies, and the completed pilot projects can only connect to the grid for trials. To prompt these companies to accept PV power unequivocally, and to purchase their output according to a feed-in tariff price based on "reasonable costs plus reasonable profits", efforts should be made in the following respects:

- Reasonable feed-in tariff prices need to be established (for off-grid PV power plants, the reasonable cost of operation and maintenance needs to be estimated).
- Standards for construction, metering and testing, as well as market access rules that can be accepted by electricity companies, need to be established.
- Electricity companies need to be made to accept PV power and to purchase it at a full-payout reasonable feed-in tariff price.
- The excess cost of generation needs to be apportioned across the whole electricity network of the country.

8.3 Policy Recommendations for Solar PV in China

8.3.1 Setting Targets

Setting bold targets is an important first step for a successful solar energy market, and it is important in terms of encouraging local producers' investment and reducing costs. While huge development has taken place in PV manufacturing industry in China, the current government target is too low. It will not help with expansion of domestic market, either further development of manufacturing industry.

8.3.2 Supportive Pricing Mechanisms

A reasonable tariff and smooth operation should be the two criteria for a good pricing mechanism. however, there is still much ambiguity in the current tariff regulations for solar energy projects in China. It is clear that a more easy-to-operate supportive tariff, such as a feed-in-tariff system similar to that operating in germany, would be both easily manageable and effective.

8.3.3 Prioritising Reform of the Energy Structure

The principles for the reform of the energy structure set by the Chinese government state that we should substitute traditional energies with new energies, replacing energy from scarce resources with energy from more widely available resources and replacing fossil fuels with renewable energies. In order for this shift to materialise, the development of renewable

energies, including solar PV, is crucial.

8.4 Roadmap for PV Development in China

8.4.1 Development Pathway

According to the Mid-to-long-term Development Plan for Renewable Energy, the cumulative installed capacity of PV in China will reach 300 MWP by 2010 and 1,800 MWP by 2020. This report concludes that the development path will more or less follow the government's expectations up to 2010. however, if strong supportive policies were set in place, a faster growth rate after 2010 could be expected.

For 2020, both a low and high target have been set. The low target of 1.8 gWP corresponds to the current government goal, whilst the high target of 10 gWP corresponds to the strong supportive measures discussed above. The following tables provide more details of these projections.

TABlE 24 CuMulATIVE InSTAllED CAPACITy (MWp) 2007-2010

year	2005	2006	2007	2008	2009	2010
Annual new capacity	5	15	25	40	60	90
Cumulative installations	70	85	110	150	210	300

Average annual growth rate:50%

FIguRE 22 PROJECTED InSTAllED CAPAICTy OF PV POWER gEnERATIOn In ChInA (2004-2010)

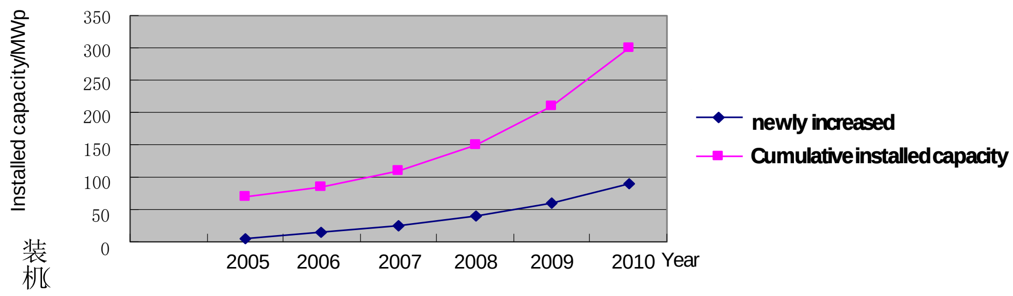


TABlE 25 CuMulATIVE InSTAllED CAPACITy (gWp) (lOW TARgET) 2010-2020

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Annual new capacity		0.12	0.125	0.131	0.137	0.143	0.150	0.156	0.162	0.170	0.176
Cumulative installation	0.3	0.45	0.575	0.706	0.843	0.986	1.136	1.292	1.454	1.624	1.800

Average annual growth rate: 4.5%

FIguRE 23 PROJECTED InSTAllED CAPACITy OF PV POWER gEnERATIOn In ChInA (lOW TARgET) 2010-2020

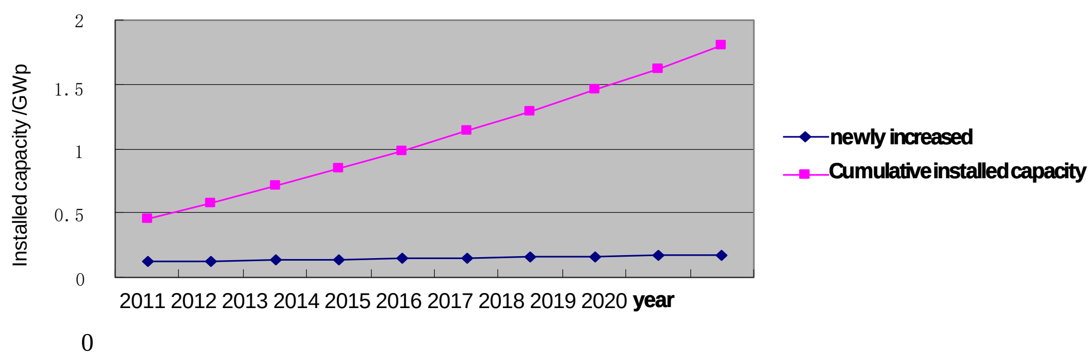
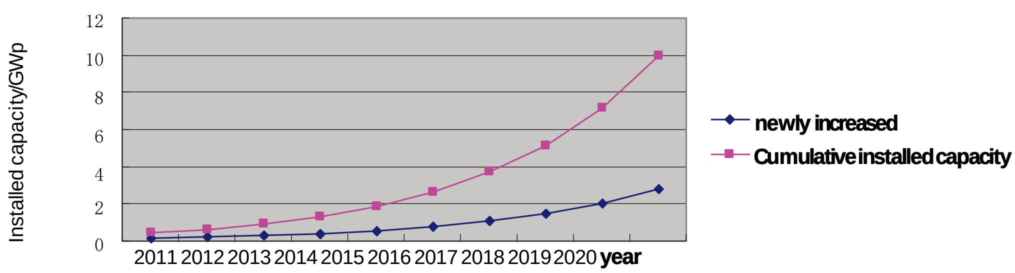


TABlE 26 CuMulATIVE InSTAllED CAPACITy (gWp) (hIgh TARgET) 2010-2020

year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Annual new capacity		0.15	0.21	0.29	0.40	0.55	0.76	1.06	1.46	2.02	2.80
Cumulative installations	0.3	0.45	0.66	0.95	1.34	1.90	2.66	3.72	5.18	7.20	10.00

Average annual growth: 39%

FIguRE 24 PROJECTED InSTAllED CAPACITy OF PV POWER gEnERATIOn In ChInA (hIgh TARgET) 2011-2020

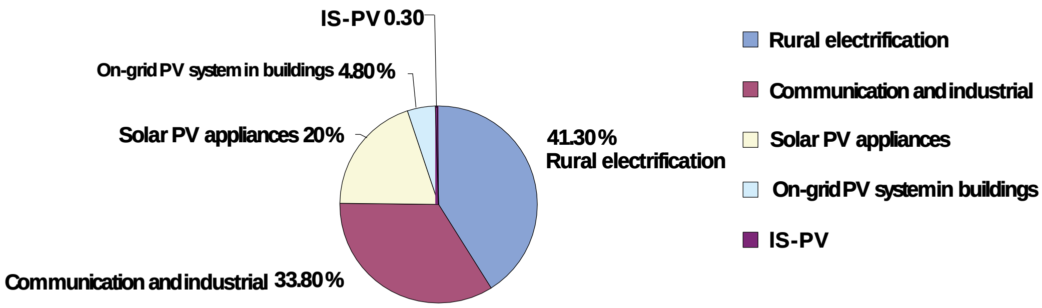


8.4.2 Projections of marketshare

TABlE 27 MARKET ShARE OF PV POWER gEnERATIOn In 2006

Category	Cumulative installed capacity / MWp	Market share / %
Rural electrification	35	41.2
Tele-communication and industry	28	32.9
Solar PV products	18	21.2
On-grid PV system in buildings	3.8	4.5
IS-PV	0.2	0.2
Total	85	100

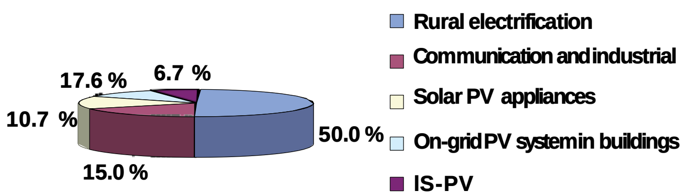
FIguRE 25 MARKET ShARE OF PV POWER gEnERATIOn In 2006



TABIE 28 PROJECTIOn OF MARKET ShARE OF PV POWER gEnERATIOn In 2010

Category	Cumulative installed capacity / MWp	Market share / %
Rural electrification	150	50.0
Tele-communication and industry	45	15.0
Solar PV products	32	10.7
On-grid PV system in buildings	53	17.6
IS-PV	20	6.7
Total	300	100

FIguRE 26 PROJECTIOn OF MARKET ShARE OF PV POWER gEnERATIOn In 2010



TABIE 29 PROJECTIOn OF MARKET ShARE OF PV POWER gEnERATIOn In 2020 (lOW TARgET)

Category	Cumulative installed capacity / MWp	Market share / %
Rural electrification	400	22
Tele-communication and industry	300	11
Solar PV products	200	17
On-grid PV system in buildings	700	39
IS-PV	200	11
Total	1,800	100

FIguRE 27 PROJECTIOn OF MARKET ShARE OF PV POWER gEnERATIOn In 2020 (lOW TARgET)

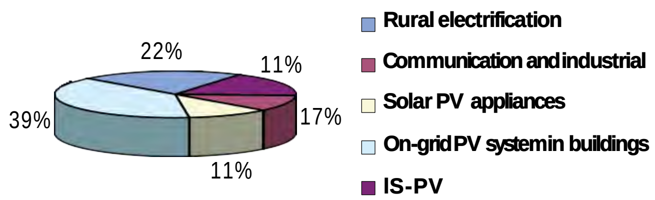
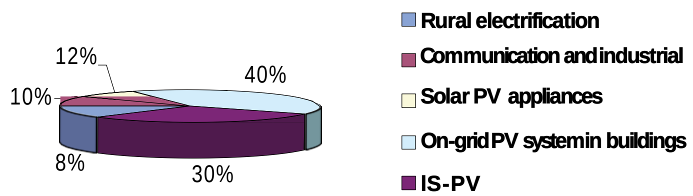


TABLE 30 PROJECTION OF MARKET SHARE OF PV POWER GENERATION IN 2020 (HIGH TARGET)

Category	Cumulative installed capacity / MWp	Market share / %
Rural electrification	800	8
Tele-communication and industry	1,000	10
Solar PV products	1,200	12
On-grid PV system in buildings	4,000	40
IS-PV	3 ,000	30
Total	10,000	100

FIGURE 28 PROJECTION OF MARKET SHARE OF PV POWER GENERATION IN 2020 (HIGH TARGET)



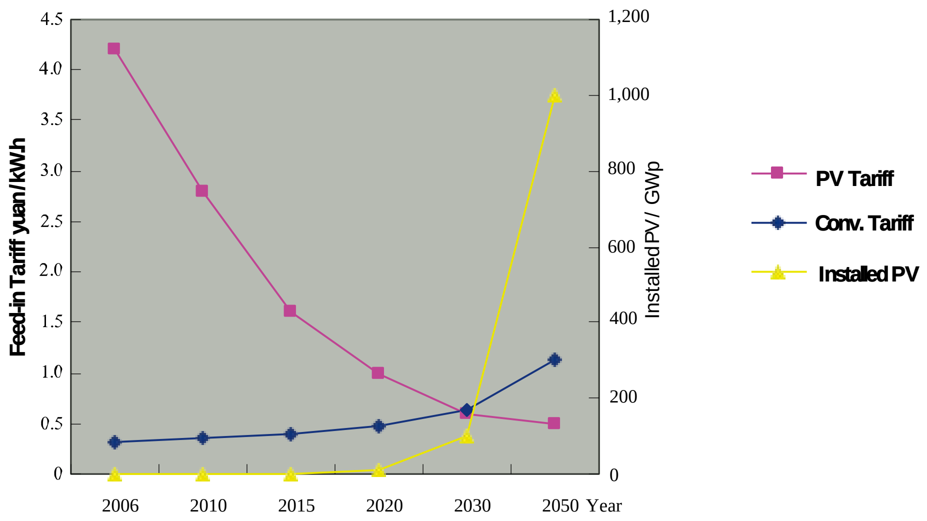
8.4.3 Overview of PV Development Roadmap

The domestic PV market is partly being driven by the rapid development of the Chinese PV manufacturing industry. For the future, however, both energy security and environmental protection, especially concerns over greenhouse gas emissions, should also provide a strong motivation for PV development. With supportive policies in place, as well as continuing technological improvement, it is entirely feasible that solar PV market growth could achieve the high target outlined here (see Table 30). From 2030, the price of solar PV is expected to be competitive with traditional power generation (see Figure 26).

TABLE 31 OVERVIEW OF CHINESE SOLAR PV DEVELOPMENT ROADMAP

year	2005	2010	2020	2030	2050
Total national power generation / TW.h	2,500	3,000	5,000	6,650	10,000
Cumulative installed PV capacity / gWp (low)	0.07	0.3	1.8	10	100
Cumulative installed PV capacity / gWp (high)	0.07	0.3	10	100	1,000
Solar PV power generation / TWh (high)	0.091	0.39	13	130	1,300
Share of national total / %	0.0,036	0.013	0.26	2.0	13.0
Price of modules / yuan / Wp	36	25	15	10	< 7
life-span of modules / years	25	30	35	> 35	> 35
Cost of system / yuan / Wp	60	35	20	15	< 10
Cost of PV power generation / yuan / kW.h	4.2	2.8	1.0	0.6	< 0.5
Cost of conventional power generation / yuan / kW.h	0.31	0.35	0.47	0.63	1.14

FIguRE 29 COMPARISOn OF COST gEnERATIOn FROM SOlAR PV AnD COnVEnTIOnAl POWER



At the same time, improvements in solar PV technology are also stimulating the development of the industry. Over the past 30 years, the cost of PV power generation has decreased from 5 uS cents per kWh to the current level of 0.5 uS cents. With further development and innovation in the technology and the scaling up of the industry, the cost is set to continue to decrease to the point where it will achieve competitiveness with conventional power generation by the year 2030 to 2050.

Figures & Tables