REPORT ON THE DEVELOPMENT OF THE PHOTOVOLTAIC INDUSTRY IN CHINA (2006-2007)

China Renewable Energy Development Project

REPORT ON THE DEVELOPMENT OF THE PHOTOVOLTAIC INDUSTRY IN CHINA

(2006-2007)

CHINA RENEWABLE ENERGY DEVELOPMENT PROJECT

June 2008

Authors:

Zhao Yuwen, zhaobts@public.bta.net.cn
Wang Sicheng, jike@public.bta.net.cn
Wang Wenjing, wjwangwj@yahoo.com.cn
Li Xudong, solarat@sina.com
Liu Zuming, mzmliu@public.km.yn.cn
Qiu Diming
Song Shuang, shuang508414@yahoo.com.cn
Grant Ramsay, grantramsay@paradise.net.nz

Supported by Project Management Office of REDP

Wu Dacheng, wu.dacheng@163.com
Ge Chun, gechun18@gmail.com
Wang Wei, *wang.wei@263.net*

INDEX

PREFACE

The Chinese photovoltaic (PV) industry grew dramatically over the period 2006 to 2007. Propelled by the booming global market, the annual production of solar cells in China reached 1,088MW in 2007. This comprised 27.2% of the entire world's production, up from 8.1% in 2005 and 17.6% in 2006. China is now the largest producer of solar cells in the world. However, the domestic PV market remained relatively limited over this period, with only 20MWp of additional capacity installed in 2007 to give an accumulative installed capacity of 100MWp at the end of 2007. This is less than 1% of the total world installed capacity which is approximately 12GWp. Over 95% of the PV products from China are targeted at the markets of Europe and North America.

Commissioned by the *Project Management Office* (PMO) of the *National Development and Reform Commission/Global Environment Facility/World Bank* (NDRC/GEF/WB) China Renewable Energy Development Project (REDP), this paper studies the development of the PV industry in China over the past few years. It is hoped that it will serve as a useful reference for those interested in China's PV industry and help to promote its further development.

This 2006-2007 research report provides both a broad overview and detailed analysis of China's PV industry. It should assist the entire industry chain, including policy makers, enterprises and investors, to more accurately understand the dynamics of the industry and hence to develop effective strategies, policies and plans for future development of the industry.

This 2006 – 2007 report is the second report commissioned by REDP on the Chinese PV industry. In 2005, REDP PMO organized a team of experts to write a *Report on the Development of the PV Industry in China* (in both Chinese and English) and this was published in August 2006. In that first report, a review was given on the status of, and prospects for, the PV industry and market in China, and policies and plans of action to further promote the industry in China were suggested. That report had a positive impact on the PV industry in China. However, due to the subsequent rapid development, the August 2006 report does not adequately reflect the current status of the PV industry in China. For this reason, in 2007 the REDP PMO commissioned a team of experts to write this updated *Report on the Development of the PV Industry in China.* Based on collected data and field surveys, this report gives a comprehensive review of the current status of the industry in China, and also makes predictions and policy suggestions for future development.

This report follows a similar structure to the report published in August 2006, but the structure has been modified where necessary to better reflect the changes in the industry over the last two years. Structure of the report:

Chapter 1: Describes the current status, trends and market developments in the global PV industry.

Chapter 2: Reviews China's energy situation, specifically the status, demand and urgency for the uptake of renewable energy in China.

Chapters 3-4: Elaborates on the current status of the PV industry in China and characteristics and trends of both China's PV manufacturing industry and domestic PV market.

Chapters 5-7: Focuses on the economic and social benefits which the PV industry is bringing to China, and the laws and regulations which are supporting the development of the industry.

Chapter 8: Explores barriers to the development of the PV industry in China and makes specific recommendations on how the government can assist the industry to overcome these barriers.

The Appendices list significant events in the development of the PV industry and trial PV power plant projects in China.

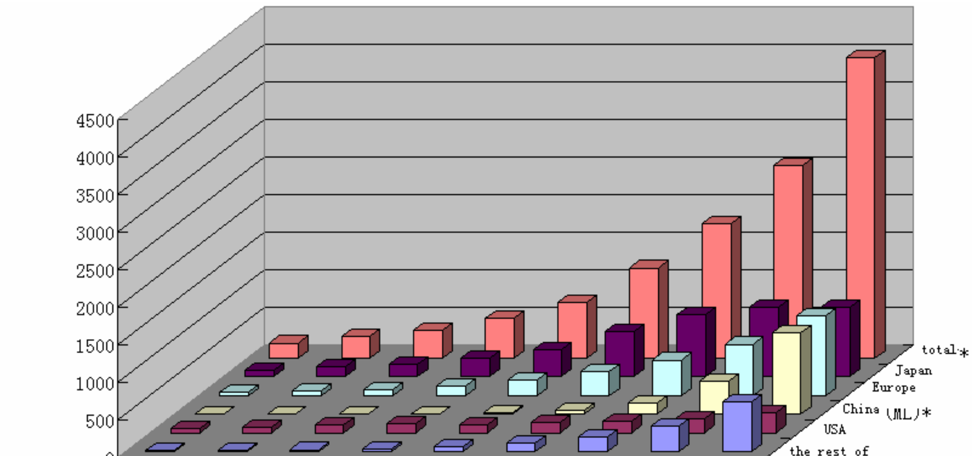
Acknowledgements

In preparing this report, the authors received encouragement and support from the NDRC, the PMO, individual experts and enterprises from the PV industry, friends and colleagues. The authors gratefully acknowledge their contribution.

1 Global Background to the Development of the Chinese PV Industry

1.1 Overview of the Global PV Industry and Market

Because of technological development, high demand for energy resources, pressure to protect the environment (global warming) and supportive policies and laws, the global PV industry and market are developing rapidly. The production of solar cells/ modules has grown at an average annual rate of 41.3% in the last 10 years (from 126MWp/year in 1997 to 4,000MWp/year in 2007) and at an average annual rate of 49.5% in the past 5 years (from 537MWp/year in 2002 to 4,000MWp/year in 2007). Despite a shortage of polycrystalline silicon materials, mainly due to the booming German market, the rate of increase still reached 42.9% in 2006 and 56.2% in 2007. Such rapid global development of a particular industry is very rare. Figure 1 shows the global production capacity for solar cells from 1998 to 2007.



	1999	2000	2001	2002	2003	2004	2005	2006	2007
the rest of world	17.5	20.02	22.9	35.5	66.4	106.5	188.5	336.5	663.15
USA	60.8	74.97	100.3	120.6	103	138.7	153.1	179.6	266.1
China (ML)*	2.5	3	4.6	6	12	50	145.7	438	1088
Europe	40	60.66	73.9	122.1	200.2	311.8	472.6	680.3	1062.8
Japan	80	128.6	172.4	252.6	365.4	604	833	926.9	920
total*	200.8	287.65	374.1	536.8	747	1201	1792.9	2561.2	4000.05

ML =Mainland China

Fig 1. Global production capacity for solar cells (MWp), 1999-2007.

Source: PV News, Vol.27, No3 March 2008

The rate of increase in PV module production capacity reasonably represents the market trend since increases in production capacity lag behind increases in market demand. Table 1 shows the global annual production capacity, and cumulative installed capacity, for the decade to 2007. By the end of 2007, total global installed capacity was greater than 12GWp; far in excess of most forecasts.

Table 1: Annual global production capacity (GWp/yr) and cumulative installed global PV capacity (GWp), over the decade to 2007.

Year	1998	1999	2000	2001	2002	2003	2004	2005	2006*	2007*
Total installed PV capacity (GWp).	0.946	1.147	1.434	1.825	2.386	3.130	4.330	6.09	8.65	12.64
Production capacity per year (GWp/ year)	0.155	0.201	0.287	0.391	0.561	0.744	1.2	1.76	2.56	4.00
Annual growth in production capacity （%）.	23.1	30	42.9	35.7	44	32.5	61.2	46.7	42.9	56.2

Source: —PV News Paul Maycock (Photon International 3/2006) * modified.

Table 2 shows solar cell/module production capacity for major countries and regions in the world in 2006 and 2007. In 2006, Japan had the greatest production capacity, followed by Germany, China, USA and Taiwan. However, the percentage of PV products sold in different countries/regions was: Germany (51%), Japan (20%), USA (10%), the rest of Europe (9%), the rest of the world (5.8%), the rest of Asia (3.6%) and China (0.6%). (See table 3). This shows that PV products are often not made in the region where the greatest demand is and that there is considerable global trade in these products.

Table 2: Solar cell/ module production capacities in different countries and regions in 2006 and 2007.

Country/ region	2006年		2007年	
	Production capacity (MW/yr)	Proportion of global capacity, ％	Production capacity (MW/yr)	Proportion of global capacity, ％
Japan	926.9	36.2	920.0	23.0
China （ML）	438.0	17.1	1,088.0	27.2
China （TW）	169.5	6.6	368.0	9.2
Germany	508.0	19.9	810.0	20.2
Rest of Europe	172.3	6.7	252.8	6.3
USA	179.6	7.0	266.1	6.7
Rest of world	166.9	6.5	295.2	7.4
Total*	2,561.2	100	4,000.1	100

Source: PV News, Volume 27, Number 3, March 2008; Wuxi, Haugwitz, Frank, Photonne International, Dec.11-12, 2007.

*Modified.

ML is mainland China, TW is Chinese Taiwan

According to the annual PV Industry Report of Solarbuzz LLC, the PV market expanded more than 62% in 2007 to give a total installed capacity of 2,826 MWp. Of this, installed PV capacity in Germany amounted to 1,328 MWp, or 47% of global installed capacity, making it the leading country. Spain, with 640 MWp of installed capacity, was second and Japan was third with 230MWp of installed capacity. Installed capacity in the US increased 57% in 2007 to reach 220 MWp, making it the country with the fourth largest amount of installed PV capacity.

Table 3 shows the world PV market share for different countries in 2007.

Tables 2 and 3 show that the European PV market was 60% of the global market in 2006, and 71% in 2007. Not only is the European PV market the world's largest, but it is also the fastest growing. The main reason for this is the "Feed-in Tariff" policy being implemented in most European countries. It is proving a very effective means of boosting the use of PV. In contrast, in 2006 and 2007 the Asian PV market shrunk by 25% and 15% respectively. This was because of a reduction in the Japanese PV market, which is a large proportion of the total Asian PV market, because the Japanese government halted its refund policy. This reduction in the Japanese market, at the same time as the world market was expanding, resulted in the total Asian share of the global market decreasing.

On the other hand, as the main solar cell production region, Asian solar cell production increased to 65% of total world production in 2007. Most of this came from China, Chinese Taiwan and Japan. In 2006, the proportions of global solar cell production from Japan, China and Chinese Taiwan were 36.2%, 17.1% and 6.6% respectively. In 2007, this changed to 23%, 27.2% and 9.2%; China became the world's leading producer. However, in contrast the number of units purchased in China remained extremely small. The reasons for this are explained later in this paper.

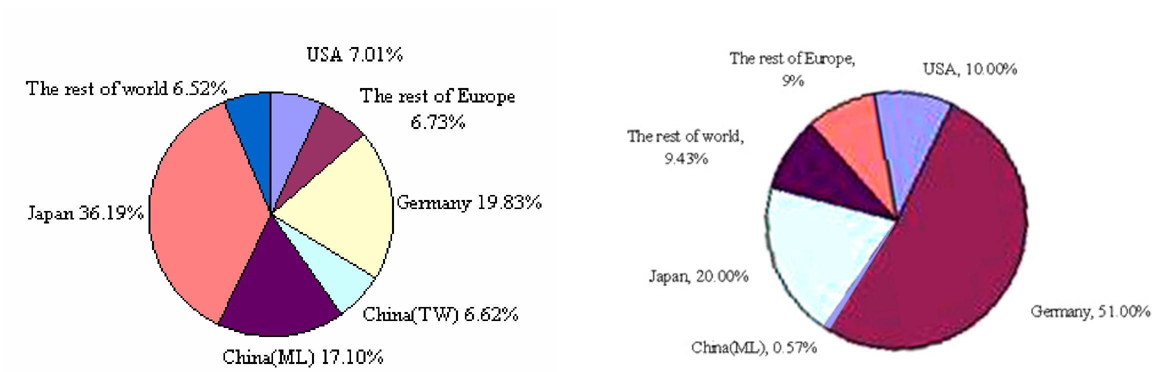
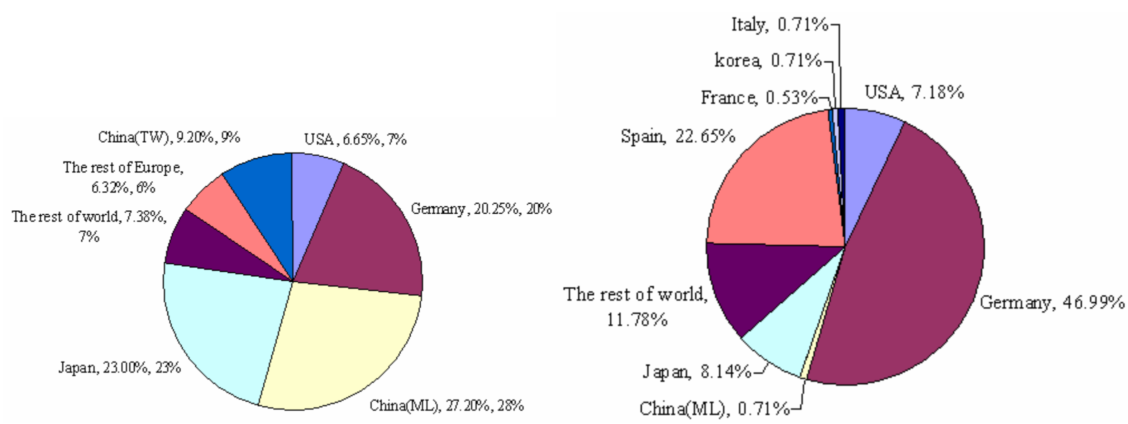


Figure2: Global production of solar cells/ modules (graph 1), and demand for these products (graph 2), by country/ region (2006).



Graph 1 Graph 2

Figure3: Global production of solar cells/ modules (graph 1), and demand for these products (graph 2), by country/ region (2007).

Table 3: Global market for solar cells/ modules by country/region, 2006 – 2007.

2006			2007			
Country	% of global sales	Rank	Country	Installed MWp	% of global sales	Rank
Germany	51	1	Germany	1,328	47.3	1
Europe(others)	9	—	Spain	640	22.8	2
Japan	20	2	Japan	230	8.2	3
US	10	3	US	220	7.2	4
—	—	—	Italy	20	0.7	5
China	0.6		China	20	0.7	5
—	—	—	Korea	20	0.7	5
—	—	—	France	15	0.5	6
Others	9.4	—	Others	333	11.9	—
Total	100	—	Total	2,826MWp	100	—

Table 4 ranks the top 16 solar cell/module manufacturing companies in the world. The total production capacity of these 16 companies accounts for 73.6% of global capacity.

Six Chinese companies are in the list: Suntech, Motech, Yingli, Jing-Ao, Solarfun and CEEG. These were rated 3rd, 5th, 8th, 11th, 13th and 16th in 2007.

Table 4: The top 16 solar cell/ module manufactures in the world, 2006 and 2007.

Company	2006年		2007年	
	Production capacity, MWp/yr	Rank	Production capacity, MWp/yr	Rank
Q-Cell(DE)	253.1	2	389.2	1
Sharp(JP)	434.4	1	363.0	2
Suntech(CH)	157.5	4	327	3
Kyocera(JP)	180	3	207	4
Firstsolar(US+DE)	60	13	207	4
Motech(TW)	102	7	196	5
Sanyo(JP)	155	5	165	6
SunPower(PH)	62.7	11	150.0	7
Baoding Yingli(CH)	35.0	—	142.5	8
Solar world(global)	86.0	9	130.0	9
Misubishi(JP)	111	6	121	10
Jing-Ao(CH)	25.0	—	113.2	11
BP Solar(global)	85.7	10	101.6	12
Solarfun(CH)	25.0	—	88.0	13
Isofotonne（SP）	61	12	85	14
Schott Solar(DE+US)	93.0	8	80.0	15
CEEG Nanjing(CH)	54.0	14	78.0	16
Others	580.8		1,056.55	
Total *	2,561.2		4,000.05	

Source: PV News, Vol.27, No.3, March 2008, *Modified

DE – Germany, JP – Japan, CH – China, US - USA, TW – Chinese Taiwan, PH – Philippines, SP – Spain

Table 5 shows global trends in the relative production capacities for monocrystalline solar cells, multicrystalline solar cells and thin film solar cells over the period 2001 to 2007. It shows a move over recent years to a relative increase in manufacturing capacity for thin film solar cells.

Table 5: Global production capacity for different types of solar cells (MWp/yr), 2001-2007.

Year	2001	2002	2003	2004	2005	2006*	2007*
Monocrystalline solar cells	133	183	237	409	672	1,141	1,651
Multicrystalline solar cells	205.1	323.8	467	727	1,013.9	1,229.7	1,999
Thin film solar cells	36	30	43	65	107	191	350
Total	374.1	536.8	747	1,201	1,792.9	2,561.7	4,000

*Modified.

Another distinct market trend has been the move to grid-connected applications. The ratio of grid-connected PV applications to overall PV applications has increased substantially over the last decade (see Table 6). It has become the main PV market and also the fastest growing (see Figure 5).

Table 6: Global percentage of PV applications which are grid-connected, 1996 - 2007.

Year	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Percentage (%)	7.9	21.3	23.5	29.9	41.7	50.4	51.4	55.5	65.9	~70	~75	~80

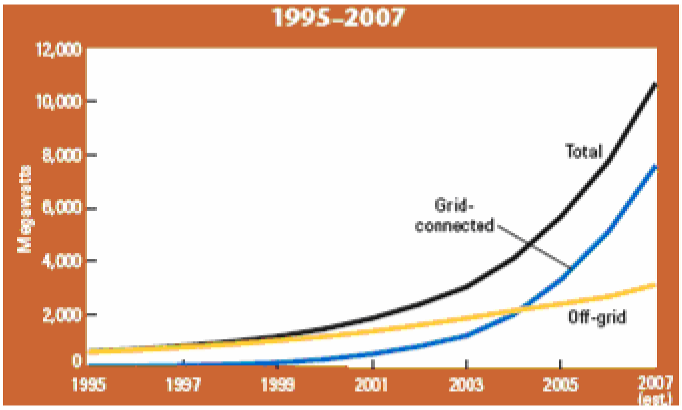


Figure 4: Market trends for PV grid-connected power generation applications.

（Source: *Renewables,* 2007 Global status Report [REN21,WWW.ren21st.net]）

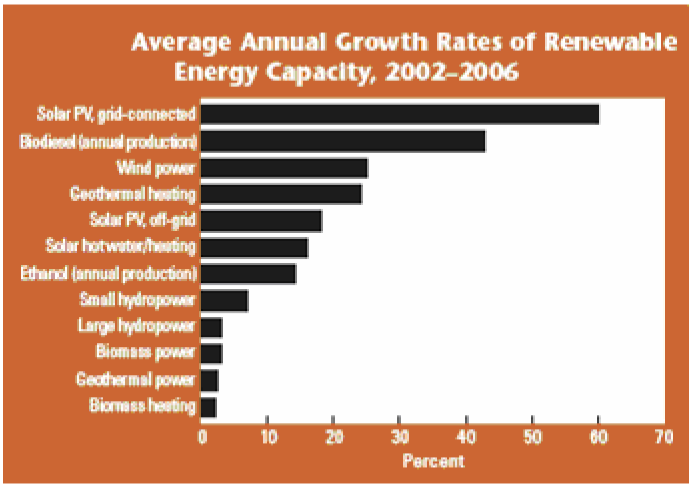


Figure 5: Average annual increases in global renewable energy capacity, 2002-2006

（Source: *Renewables*, 2007 Global status Report [REN21,WWW.ren21st.net]）

1.2 Market Trends, Forecasts and Roadmaps for the Global Photovoltaic Industry

1.2.1 World Energy Demand and the Rate of Introduction of Renewable Energy Sources

The first half of the 21st century will see fundamental changes in energy structure as renewable energy sources gradually replace fossil fuels. Many nations and organizations from around the world have predicted, with similar results, the rate at which renewable energy should replace fossil fuels based on forecasts of total world energy demand and fossil fuel consumption and depletion rates. These results are summarized in Table 7.

Table 7: Forecast rate of replacement of fossil fuels with renewable energy.

Year	2000	2010	2020	2030	2040	2050	2100
substitution rate（%）	～5	～10	～20	～30	～40	>50	>80

Even though renewables are recognized as the most important energy resource for the future, without appropriate policies to support and boost their uptake it is unlikely that the forecast replacement rate shown in table 7 will ever be realized. This has very serious implications for sustainable development.

Another harsh reality is that, without action, and according to current fossil fuel consumption rates, by the middle of the 21st century fossil fuel depletion and environmental deterioration will cause disastrous results that may threaten the very existence of the human race. Global energy demand and resource depletion have already caused the price of oil to exceed $120/barrel. Behind all factors, fossil energy resource depletion is the main reason.

Energy and environmental crises have forced nations to speed up the development of renewable energy, not only in technical terms, but also through policies and laws to boost market development. There has been a specific focus on photovoltaic and wind energy applications.

1.2.2 Prospects and Forecasts for the PV Industry

Many governments and enterprises see great potential for the PV industry and have put large efforts into developing it. The best evidence of the potential comes from the forecasts of prominent institutions and from the PV roadmaps, and their corresponding plans and execution status, of developed nations.

(1) International Energy Association (IEA) forecast for the PV industry

The IEA forecasts that 1% of total world electricity generated in 2020 will be from PV, and 20% in 2040 (see Figure 6).

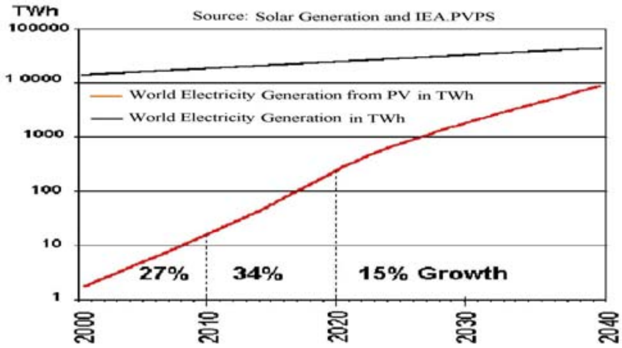


Figure 6: IEA forecast of PV electricity generation

(2)European Photovoltaic Industry Association (EPIA) forecast for the PV industry

EPIA forecasts that, by 2020: global production capacity for PV modules will reach 40GWp, total installed capacity will be 195GWp and PV-generated electricity will be 274 TWh, 1% of total world electricity generation. By 2040, the EPIA predicts that: the cost of a solar cell module will be reduced to US$1/Wp and that PV-generated electricity will reach 7,368 TWh, 21% of total world electricity generation (Renewable Energy World, 2003).

(3)National PV electricity generation roadmaps

The United States, Europe and Japan forecast that accumulative PV installed capacity will reach 200GWp by 2020 (see Table 8), of which more than 50% will be located in the United States, Europe and Japan. Also, with technology improvements and increasing economies of scale, the cost of producing electricity by PV is expected to gradually reduce to match the cost of electricity generation by other means (see Table 9). Data from recent years shows that cost reduction is occurring more quickly than projected in the roadmaps, even with the recent polysilicon shortage. With the ever increasing cost of other forms of energy currently in common usage, PV electricity is expected to be cost competitive with these by 2020.

Table 8: Forecasts of accumulative installed PV electricity generation capacity, from national roadmaps (GWp).

Year	2000	2010	2020	2030
United States	0.15	2.1	36	200
Europe	0.15	3.0	41	200
Japan	0.25	4.8	30	205
World Total（AIP）	1.0	14.0	200	1,850

Source: Japanese, US, EPIA and EREC (European Renewable Energy Council) 2040 scenarios

(EREC - European Renewable Energy Council, EPIA- European Photovoltaic Industry Agency, AIP - Advanced International Policy Scenario)

Table 9: Forecast cost of PV electricity

Year	2004	2010	2020
Japan （Yen/KWh）	30	23	14
Europe（Euro/KWh）	0.25	0.18	0.10
US（Cents/KWh）	18.2	13.4	10.0

Source: Japanese, US, EPIA and EREC (European Renewable Energy Council) 2040 scenarios

The above forecasts, from esteemed organizations and national roadmaps, are highly consistent. They show that there is potential for PV electricity generation to be an important part of future efforts to replace fossil fuel energy with renewable energy.

(4) Five year forecast for global PV electricity generation

Michael Rogol (Photonne Consulting, Solar Annual 2007) has made a five year forecast (2007-2011) for: world PV cell/module manufacturing capacity, annual percent increase in manufacturing capacity, average module sales price and average system installation price (see Table 10 and Figure 7). Rogol's projections are very optimistic and higher than most other forecasts. For example, Rogol predicts solar cell/module production capacity to be more than 15GWp by 2010, even though this is more than his predicted accumulative installed capacity at that time of 14GWp.

Table 5 shows that thin film solar cell production capacity has been steadily increasing over the last few years. Figure 7, the forecast of Rogol, predicts that it will reach 2GWp/yr by 2010, 13.2% of the total PV manufacturing capacity of 15.1GWp/yr forecast for that year. A shortage of solar grade silicon feedstock, and developments in thin film manufacturing technology, are the main forces driving the development of the thin film solar cell industry. However, while the forecasts shown in figure 7 for total production capacity in 2007 match the actual figures shown in table 5 (4GWp), Rogol's forcast for the relative proportion of thin film solar cells was double the actual production of 350MWp. This casts some doubts on Rogal's predictions and suggests that more analysis is required.

Table 10: Five year forecast of global solar cell manufacturing capacity and price.

	2005	2006	2007	2008	2009	2010	2011
Solar cell/module manufacturing capacity(GWp/yr)	1.7	2.6	4.0	6.1	10.2	15.1	20.5
Rate of increase in manufacturing capacity (%)	44	58	53	54	66	48	36
PV module average sales price ($/Wp)	3.7	4.3	4.1	3.8	3.7	3.5	3.3
Average system installation price($/Wp)	7.1	7.8	7.5	7.0	6.6	6.2	5.9

Source: Rogol, M.; Photonne Consulting, Solar Annual 2007)

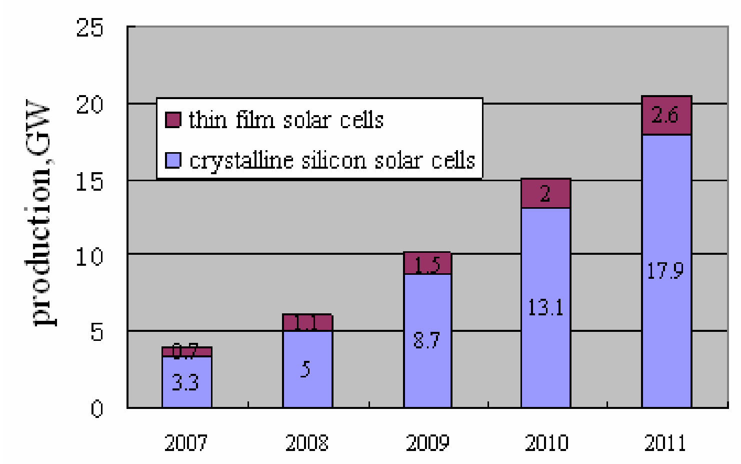


Figure 7: Five year forecast of PV industry manufacturing capacity (GWp/yr)

Source: Rogol, M.; Photonne Consulting, Solar Annual 2007)

1.3 Global Advancements and Trends in PV Technology

Technology advancement has been the major factor in reducing the cost of electricity generation by PV over the years and in developing the size of the PV market. Many years of R&D achievements have manifested themselves in advances such as:

- improvements in solar cell conversion efficiency
- reductions in wafer thickness, and
- advancements in manufacturing technology.

1.3.1 Improvements in Solar Cell Conversion Efficiency

As a result of the transfer of new technology to industry, including advanced fabrication and assembly technologies, commercial silicon solar cell conversion efficiencies have reached as high as 20% with stable properties. The efficiency varies for specific types of solar cells:

- c-Si : 16% - 20%,
- p-Si : 15% - 18%,
- a-Si thin film: single junction, 5% - 7%; double junction 6%~ 8%,
- a-si/u-si layer solar cell: 8% - 10%.

1.3.2 Reductions in Solar Cell Wafer Thickness

Reducing wafer thickness is an effective method to lower silicon material consumption and cost. The wafer thickness of commercial solar cells has been reduced from 500μm to 180-200μm over the past 40 or so years (see Table 11 and Figure 8).

Table 11: Reductions in solar cell wafer thickness over the last 40 years

Period	Wafer Thickness (μm)	Silicon Consumption (Tonnes/MWp)
1970s	450-500	>20
1980s	400-450	16-20
1990s	350-400	13-16
2006	200-220	10-11
2007	180-200	9-10
2010	160-180	~7

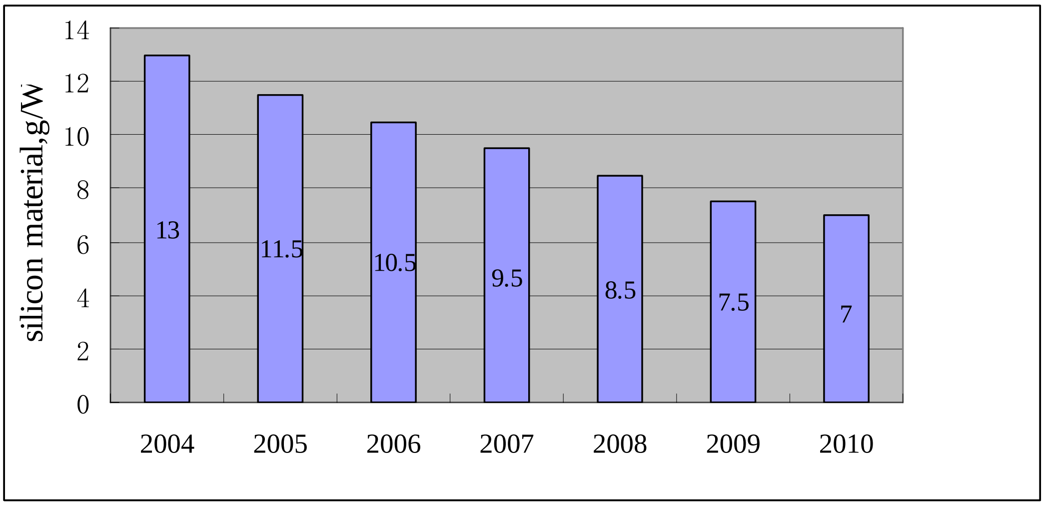


Figure 8: Reduction in solar cell silicon material consumption

1.3.3 Increasing the Scale of Solar Cell Manufacture

Increased scale of manufacture and increased automation are the major factors responsible for cost reduction in solar cell production. Solar cell manufacture at individual enterprises has grown from 1-5 MWp/year in the 1980s to 5-30MWp/year in the 1990s, 25 - 500MWp/year in 2006 and 25-1,000MWp/year in 2007. The relationship between manufacturing size and production cost is best illustrated by the LR (Learning Curve Rate). For the PV industry, data from over 30 years show LR = 20%, which is the highest amongst all renewable energy resources and is a very good example for modern industry.

1.3.4 Rapid Decline in Solar Cell Module Cost

PV module cost has decrease by 2 orders-of-magnitude over the last 30 years. In 2003, the average cost reported by major global manufacturers was 2 -2.3 US$/Wp, with a sales price of 2.5 -3 US$/Wp. The cost increased after 2004 due to a feedstock shortage. Figure 9 plots the silicon solar cell module price learning curve. Although there are some perturbations, the overall price of solar cell modules follows a more or less straight downward line. If there are technology breakthroughs, such as those which could see an increase in the market share of thin film solar cells, the rate of drop in price could be even higher.

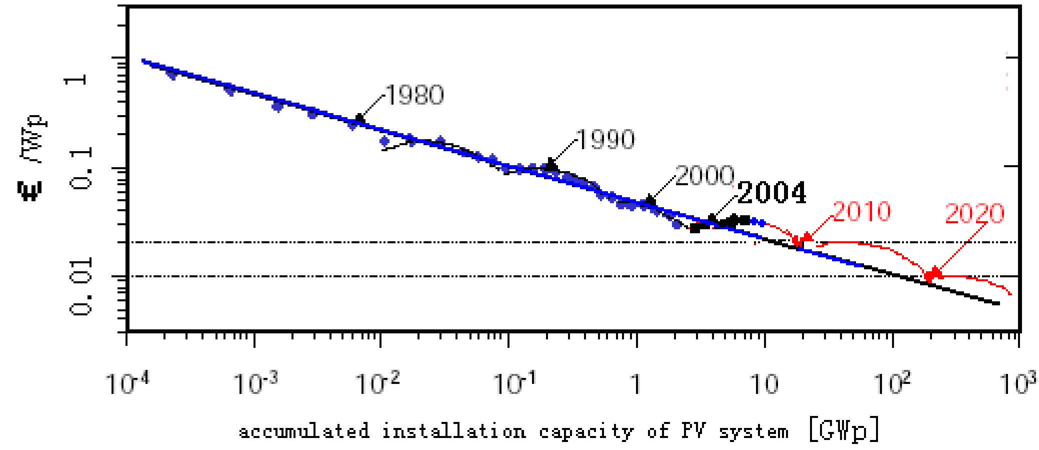


Figure 9: Change in the cost of producing silicon solar cell modules as the scale of production increases (price learning curve).

Source: *Future Direction of PV*, 1st Workshop, Tokyo, 3-4 March, 2005.

Figure 10 shows the average global cost in 2006 of PV modules and systems. Figure 11 shows the forecast to 2010 of the cost of electricity generation by PV. These graphs both show that, as the cost of PV modules decreases, so too does the cost of PV electricity generation.

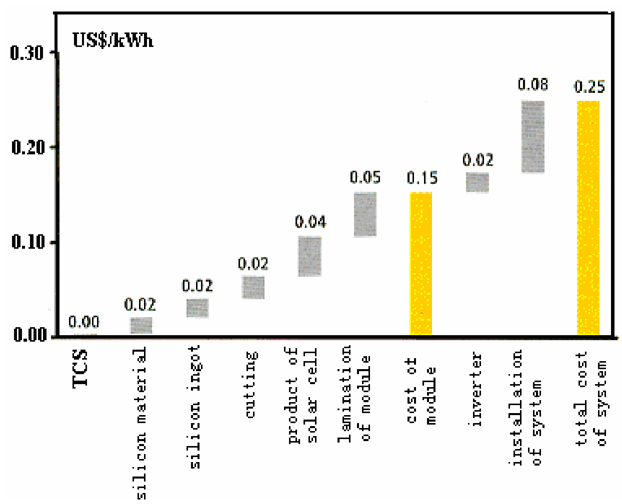


Figure 10: PV System Average Cost (2006)

Source: Photonne Consulting

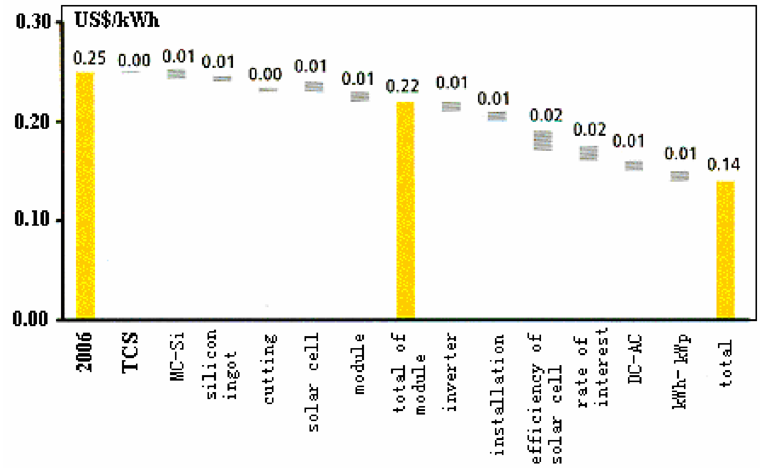


Figure 11: Forecast of PV Electricity Generation Cost (2010)

Source: Photonne Consulting

1.3.5 Rapid Growth in the Production of Thin Film Solar Cells

The thin film solar cell industry has received a boost in recent years from the silicon feedstock shortage. Amorphous silicon solar cell production line capacity has reached 20-40MWp/year at some enterprises (Kaneka, 20MWp/year; Uni-solar, 25MWp/year; AM, 40 MWp/year) with a consistent product efficiency of 5% - 7%. In 2006, world thin film solar cell production reached 191MWp (amorphous silicon (a-Si) and microcrystalline silicon (uc-Si) solar cells, 147MWp; cadmium telluride (CdTe) solar cells, 40MWp; copper indium gallium selenide (CIGS), 4MWp), 7.2% of the total global solar cell market. In 2007, thin film solar cell production reached 350MWp (a-Si and uc-Si,270MWp; CdTe, 74MWp, CIGS, 6MWp), 8.75% of the total global solar cell market. Silicon-based thin film solar cells (a-Si, uc-Si, and a-Si/uc-Si) are the mainstream products, comprising 77% of total global thin film solar cell production. Table 12 lists major manufacturers and their production capacities.

Table 12: Major manufacturers of silicon thin film solar cells and their production capacities.

Manufacturer	Production Capacity (MWp/year)	
	2006	2007
Bangkok Solar	12	12
EPOD	—	8
Energy Photovoltaics Inc.	2.4	2.4
Free Energy Europe	1.2	1.7
Fuji Electric Systems	18	18
Heliodomi SA	3	3
ICP Solar Technologics Ltd.	3	3
Kancka	30	55
Mitsubishi Heavy Industries	50	70
Schott Solar	3	30
Sharp	15	15
Sinonar	3	3
Solar Cell Ltd.	1.2	
Terra Solar	2.5	2.5

Tianjin Jingneng Solar Cell	1.6	
United Solar	50	100
CSG Solar	12	25

After silicon, the next two major thin film solar cell substrates are CdTe, which captures 21.4% of global solar cell production, and CIGS ((Cu)–indium (In)–gallium (Ga)–selenide (Se)-sulfide) which has 1.72% of global production. CdTe Solar Cell producers are *First Solar* (US) and *ANTEC* (Germany). *First Solar* (Previously *Solar Cell Inc.*) uses steam transport CdTe film deposition, giving average efficiencies of 10%. It currently has two production lines under construction; in Malaysia and in Germany. ANTEC has had, since 2001, a 10MWp/yr fully automated production line using CdTe/CdS thin film near space vaporizing deposition technology.

CIGS module efficiency can consistently reach 10% -12%. However, because of complicated physics and process issues, CIGS industrialisation has been very slow. Companies producing CIGS modules include Solar Hongda and Shell Solar.

Table 13 shows that, since 2004, the rate of production of thin film solar cells has been increasing.

Table 13: Global thin film production capacity, 2001-2007 (MW/yr)

Thin film	2001	2002	2003	2004	2005	2006	2007
a-Si,μc-Si	33.7	28.0	40.5	47.8	84	147	270
CIGS	0.7	0.3	0.5	3.6	2	4	6
CdTe	1.5	1.6	2.0	13.2	21	40	74
Total	35.9	29.9	43.0	64.6	107	191	350

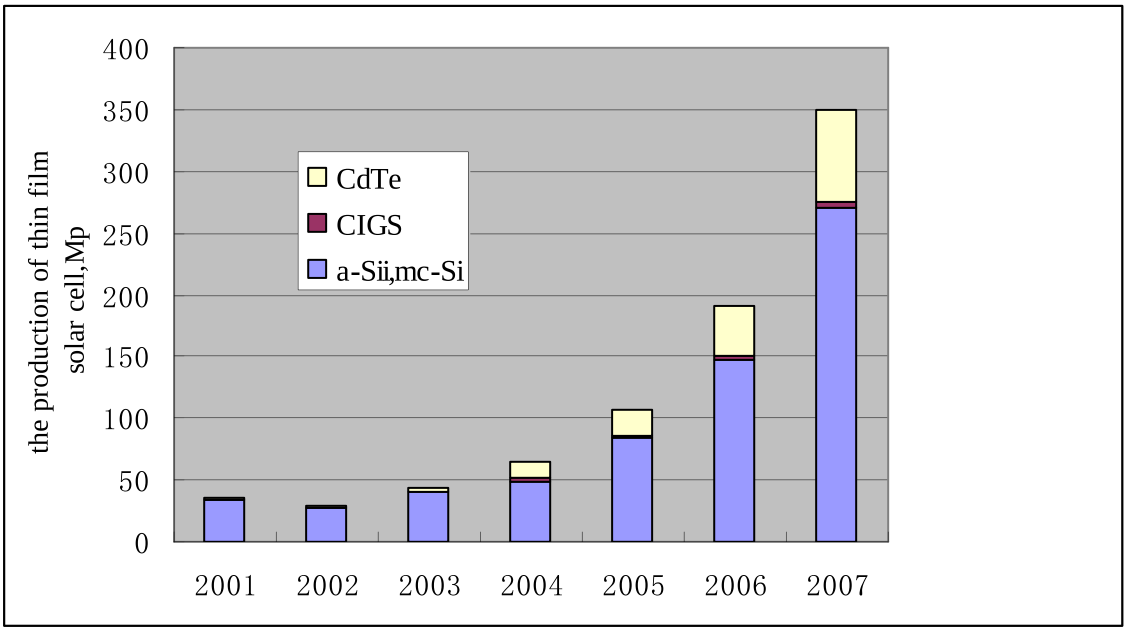


Figure 12: Global thin film production capacity, 2001-2007 (MWp/yr)

1.3.6 Development of Specialized PV Manufacturing Equipment

Over the past three decades, advances in manufacturing technologies for the PV industry have played an important role in the development of the industry and the reduction in the cost of PV power. For instance:

- The invention and further improvement of a polycrystalline silicon casting furnace made possible the large-scale casting of polycrystalline silicon. Due to the advantage of cost, the production of polycrystalline silicon solar cells increased continually. It eventually exceeded mono-crystalline silicon solar cells to become the dominant product in the PV market.
- The invention of the wire saw greatly increased the manufacturing efficiency of silicon wafers, decreasing both the losses incurred in slicing silicon and the thickness of the wafers. This has played an important role in reducing the cost of crystalline silicon solar cells.
- Plasma enhanced chemical vapour deposition (PECVD) silicon nitride equipment, used in the passivation of polycrystalline silicon solar cells and anti-reflective coatings, played an important role in increasing the efficiency of commercial polycrystalline silicon solar cells and has been extended to monocrystalline cells.
- Automatic silk printing machines and selection machines have also played an important role in improving the performance of commercial solar cells, increasing production efficiency and enlarging the scale of production.

1.4 Analysis of the Global PV Industry

(1) Technology advancement - its importance and its limitations.

It has been a long time since the appearance of the first usable mono-silicon solar cell modules (efficiency 6%). Although the sales price of PV modules has dropped drastically, from US$1500/Wp in the 1960s to US$3/Wp in the 2000s, through technology improvement, electricity generated from PV still costs 8-10 times more than when generated from fossil fuels or hydro-power. It is forecast that the cost of electricity generated by PV will be comparable to the cost of electricity generated by fossil fuels or hydro-power by the year 2050. This is based only on forecast technology advances (including government science and technology promotion programs). Uptake of the technology based on technological advances alone is likely to be relatively slow, and government support would be required to speed up the rate.

(2) Government policies to promote PV, and limitations to this.

Since the 1970s, the US government has passed a series of energy bills to encourage PV electricity generation. The "Million Solar Roofs Plan" was proposed during the Clinton period in the 1990s and was finally approved by the Governor of California in 2006. As early as 1974, Japan rolled out its "Sunshine Plan", putting PV electricity generation as the major resource for future national electricity generation. An important aspect was to accomplish rooftop solar grid-connected power generation. The Government of Japan provided rebates as high as 70% of the cost of installed PV systems. This policy accomplished its historical goal in 2006 when the cost of PV electricity generation became comparable to that of traditionally-generated electricity. This policy successfully positioned Japan as the world's largest PV module producing country as well as the world's largest PV module market. Though on one hand Japan set a role model for government support and commitment to PV industry development, on the other hand it was a model rarely applicable outside of Japan because other countries do not have the same economical power and policy consistency. Political structures and social pressures in other countries do not allow policymakers to spend huge amounts of national income to support the PV industry over the long term. As a matter of fact, countries outside of Japan have introduced many policies to encourage the PV industry but with very limited effect.

(3)Propelling force of the "feed-in tariff law"

Since the late 1990s, Germany has done careful research and analysis on major PV technologies in the world. The analysis included trends in PV module cost reduction and the scale effect, which was shown by "learning curve analysis" to result in a 20% reduction in cost whenever production capacity doubled. The results showed that the costs of all types of solar cells (silicon substrate, CdTe and CIGS) could be reduced to less than US$1/Wp by expanding production capacity in factories. This research provided theoretical support for the PV feed-in tariff policy.

The "New (Revised) Renewable Energy Resources Act", the EEG (a new feed-in tariff law), came into effect in Germany in 2004. The original feed-in tariff law went into effect in Germany in 2000. In the 2000 Act the PV feed-in tariff price was set at 0.99 Mark / kWh, and from 2005 the price was to decrease by 5% every year for two decades. The 2004 amendment increased the feed-in tariff to make it more in line with the actual costs of power generation and more beneficial to investors. The new Act also makes the tariff easier to administer. The feed-in tariff varies according to the type of renewable energy technology and its size and location (see Table 14).

However, the most important point is that the revised law is is based on a thorough understanding of the energy market in Germany, so that government interventions to regulate the market and encourage the development of renewable energy, through feed-in tariffs, could be effectively designed and implemented. One feature of feed-in tariffs is that they do not put a burden on government budgets so overcome a potential barrier to their implementation. The costs of a feed-in tariff scheme are borne by the electricity consumers.

Table 14: Feed-in tariff for PV under the "New Renewable Resources Act" in Germany, effective from January 2004.

Type of system	Feed-in tariff (Euro/kWh)		
	<30 kWp	30~100 kWp	>100 kWp
Building rooftop	0.574	0.546	0.540
Curtain wall	0.624	0.596	0.590
Ground-mounted PV system	0.457		

The introduction of the feed-in tariff laws in Germany was very effective and led to a rapid increase in the market for PV systems. The German market surpassed the Japanese market to become the largest and fastest growing in the world. New installed PV system capacity has been 0.5–1 GWp/yr since 2004. The accumulative installed capacity had already exceeded 3.6GWp, the European white paper target for 2010, by 2007. The German PV cell manufacturing industry has also surpassed the USA to become the second largest in the world.

The feed-in tariff laws in Germany fix tariffs for approved renewable energy projects for a 20-year period from the date of plant commisisioning. The laws require that the tariff for PV electricity be reduced by 5% per year (and by 6.5% for ground-mounted systems). This reduction will stimulate a decrease in production costs. Table 15 shows the tariffs for 2007 after these incremental annual price cuts. (www.solarbuzz.com/FastFactsGermany.htm).

Table 15: Feed-in tariff for PV electricity in Germany, 2007.

Type of system	Feed-in tariff (Euro/kWh)		
	<30 kWp	30~100 kWp	>100 kWp
Buildings and walls	0.492	0.468	0.463
PV buildings		0.05	
Ground-mounted PV system	0.380		

It is now frequently realized that feed-in tariffs can be a very effective tool to promote the PV industry, and that the successful large-scale introduction of PV can bring great social, economic and environmental benefits. The example of Germany has been recognized and followed by many countries. So far, feed-in tariff laws (including cost-sharing laws) have been executed in more than 40 countries and regions around the world. Table 16 lists major participants.

Table 16: Major countries employing feed-in tariff laws.

Country	Feed-in tariff, Euro/kWh	Period of tariff
Germany	0.55(average)	20
Belgium	0.45	20
Greece	0.49	20
Italy	0.45	20
Portuguese	0.44	15
Spain	0.42	25
Washington(US)	0.43（US$/ kWh）	10
California（US）	0.50（US$/ kWh）	3
Korea	0.58	15

A large-scale move to the use of renewable energy directly addresses the major issues being faced in the 21st century: environmentally sustainable energy production and environmentally sustainable development. Feed-in tariff laws (including cost-sharing laws) are probably the most effective innovation that has been used globally to effectively promote the rapid deployment of renewable energy.

One major obstacle to the adoption of PV for electricity generation is that PV electricity is more expensive than electricity generated from fossil fuels. The great value of feed-in tariff laws is that they oblige consumers, through legislation, to purchase electricity at above market rates set by the government. This helps to overcome this cost disadvantage and makes the use of PV electricity, with its environmental sustainability benefits, more appealing.

The gradual reduction of the tariff over time will encourage improvements in product quality and reductions in production cost, and through market competition the strongest and the best companies will survive and grow, thus promoting the rapid, healthy long-term development of renewable energy resources.

2 Significance of PV Electricity Generation to Energy Supply and Environmentally Sustainable Development in China

2.1 Conventional energy resources in China

Conventional fossil fuel energy resources are finite, whether in China or elsewhere in the world. Figure 13 gives a comparison, made in 1999, of how long the conventional primary energy reserves of China are likely to last (reserves/rate of usage) compared with the global situation. This shows that the reserves of primary energy in China will last less than the global average, and that the conventional energy resource situation in China is much more severe than in many other countries.

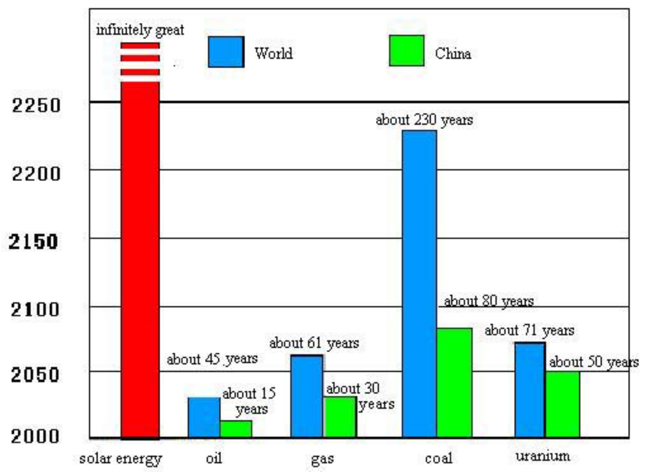


Figure 13: Comparison of energy reserves in China with global reserves

2.2 Composition of Energy Consumed in China

China is a major energy producer as well as a major energy consumer. The total energy consumption in 2006 was 2.46 billion tonnenes of coal equivalent (tce), which is 9.3% more than in 2005. The composition of the primary energy consumption in 2006 was: coal 69.7%, oil 20.3%, natural gas 3.0%, hydropower 6.0%, nuclear 0.8% and other sources 0.2% as shown in Figure 14. Over two-thirds of energy came from coal energy, which is very polluting. This high reliance on coal is in sharp contrast to the global pattern of energy usage. Also, the quantities of crude oil and natural gas imports have been steadily increasing. Crude oil imports reached 1.5 billion tonnes in 2006. The composition of energy comsumed in China is not good either economically or environmentally and is in desperate need of change. At the same time, China has abundant solar energy resources which are favorable for the development of the PV electricity generation industry and sustainable development.

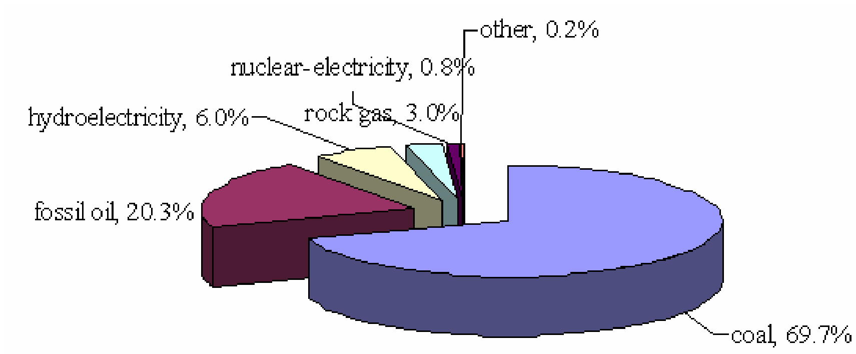


Figure 14: Composition of energy consumed in China in 2006.

2.3 Electricity Demand in China

Because of rapid economic development, electric power demand in China has increased at a rate of more than 20% annually since 2001. The energy resources used for electric power production in China in 2004 are given in Table 17. Based on forecasts of economic development and electricity supply in China, there will be a shortfall in electric power in 2010 and 2020, and electricity generated by renewable energy resources will be necessary. Table 18 gives forecasts made by the *Chinese Electric Power Research Institute* of electric power production capacity in China in the years 2010, 2020 and 2050. Estimates of electric power supply shortfalls in China in 2010 and 2020 are given in Table 19 and Figure 15.

Table 17: Electricity production in China in 2004

Energy source	Installation Capacity (GW)		Output（TWh）	
	Capacity	Percentage of total power	Output	Percentage of total power
	（GW）	（%）	（TWh）	（%）
Coal	324.9	73.5	1807.3	82.4
Hydro	108.3	24.4	328	15.0
Nuclear	6.84	1.5	50.1	2.3
Other	2.80	0.6	6.3	0.3
Total	442.8	100	2191.7	100

Table 18: Forecast installed electric power generation capacity and output in China in 2010, 2020 and 2050.

Year	Installed Capacity（GW）	Output（TWh）
2004	442	2190
2005	517	2494
2006	623	2834

2010	685	3140
2020	1112	5090
2050	2000	9270

Source: Chinese Electric Power Research Institute

Table 19: Forecast shortfall in installed generation capacity in China in 2010 & 2020 (GW).

Year	Coal	Hydro	Nuclear	Other	**Shortfall**	Total
2010	500	100	16.4	15.7	52.9	685
	73%	14.6%	2.4%	2.3%	7.7%	100%
2020	750	170	53	48	91	1112
	67.4%	15.3%	4.8%	4.3%	8.2%	100%

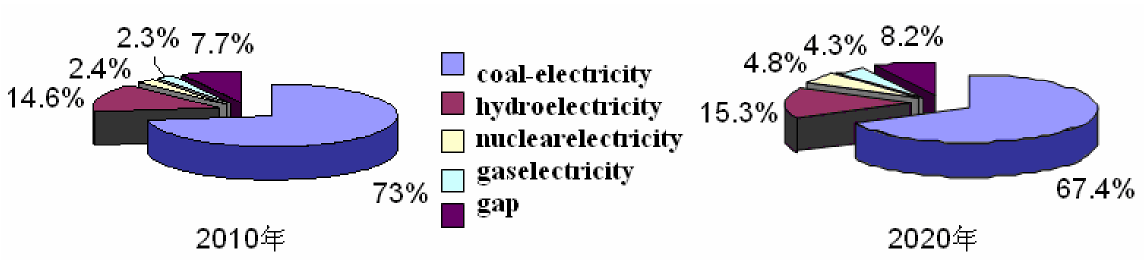


Figure 15: Forecast shortfall in installed generation capacity in China in 2010 & 2020 (GW).

2.4 The Necessity of Developing the PV Industry

2.4.1 Rapidly Increasing Energy Consumption In China

China's energy consumption has increased along with its economic progress. Table 20 gives the energy consumption from 2002 to 2006 and the rates of increase. The speed of increase in energy demand has exceeded that planned for. The target is for the GDP of China to triple by 2020 and for energy consumption to double by 2020. Inadequate energy supply would generate a huge barrier to economic development, so it is imperative to speed up renewable energy resource development.

Table 20: China's total energy consumption from 2002 - 2006 and the rate of increase. (billion tons standard coal)

Year	2002	2003	2004	2005	2006
Consumption	1.518	1.75	2.032	2.247	2.457
Rate of Increase	6.0%	15.3%	16.1%	10.6%	9.3%

2.4.2 Rapid Depletion of Conventional Energy Resources

Technology in Chinese industry still tends to be relatively energy inefficient, and traditional energy-intensive industries make up a major part of Chinese industry. This means that energy consumption per unit of GDP is much higher than the world average (see Table 21), contributing to rapid depletion of fossil energy resources.

Table 21: Comparison of energy consumption between China and the rest of the world.

	China	US	JP	OECD	Global Average
1996 energy consumption per unit GDP	1.67	0.55	0.23	0.44	0.57
1997energy consumption per person	1,118	11,530	5,820	6,580	2,080
1997electricity production per person	919	13,739	8,132	8,021	2,090(1996)

2.4.3 Huge Future Electricity Demand in China

There will be considerable electricity shortages in China in 2010 and 2020 even allowing for very optimistic targets for fossil fuel, nuclear and hydro electricity development. It is therefore imperative to increase the rate of development of the renewable energy electricity generation industry to cover the shortfall in electricity supply while improving the environment and realizing sustainable energy production.

2.4.4 Severe Environmental Deterioration in China

The main energy source in China is coal, accounting for more than two-thirds of total energy supply. This is in sharp contrast to the global pattern of energy supply (see Table 22). China generates more SO_2 than any other country, due largely to coal combustion (see Table 23), and creates the most acid rain . Besides electricity generation, direct coal combustion is used in many applications, and these often generate worse pollution than when it is used for electricity production. Pollutants from coal combustion are the major components of China's air pollution, as illustrated in table 24. And SO_2 is not the only problem. In 2007, China generated 6.02 billion tonnes of CO_2, surpassing the United States, which generated 5.91 billion tonnes of CO_2, to become the worst CO_2 generating country. This creates great pressure to reduce energy usage and pollution discharge, to change the composition of the energy supply and to improve the sustainability of energy supply in China.

Table 22: Comparison of energy supply sources between China and the rest of the world.

	Rest of the World	China
Coal	24.7%	67.0%
Oil	38.5%	23.6%
Natural Gas	23.7%	2.5%
Nuclear	6.6%	0.4%
Hydro	6.5%	6.5%

Table 23: SO_2 generated from electric power by burning coal in China.

	2004	2005	2006
SO_2 from coal burning（10,000 tonnes）	1,200	1,300	1,350
Total SO_2（10,000 tonnes）	2,255	2,549	2,589
% of total SO_2 emissions arising from coal combustion	53.2	51.0	52.1

Table 24: Percentage of total pollutants in China arising from coal combustion.

Pollutant	Percentage of pollutant arising from coal combustion.
SO_2	87%
CO_2	71%
NO_x	67%
Dust	60%

Even thought energy-related discharges per person have been historically lower in China than in the USA and other developed countries, it is unquestionably the responsibility of the government to take urgent actions to improve the sustainability of energy supply in China. This will require the speeding up of renewable energy development, optimizing the composition of energy supply sources including increasing the percentage of energy coming from clean sources, and reducing greenhouse gas and poisonous gas discharges. Such actions will be beneficial for both the country and its people in the long run.

2.5 Advantages, and Future Leading Role, of PV Electricity Generation

2.5.1 Advantages of PV Electricity Generation

The basic theory of PV electricity generation is to utilize the PV effect of solar cells (semiconductor P-N diodes) to directly convert solar radiation energy to electricity. The electricity generation process from PV is simple; there are no moving mechanical parts, no fuel consumption, no pollutant discharges (including greenhouse gases) and no noise. Also, solar energy is limitless and available everywhere. The main material for solar cells is silicon, which comprises 25.8% of total world materials and is therefore virtually limitless. Compared to fossil fuels, wind and biomass, PV is the most promising renewable energy source for electricity generation because of its following unique features:

- PV electricity generation is a direct conversion from photons to electrons - there is no intermediate conversion process (such as from thermal energy to mechanical energy, or mechanical energy to electromagnetic energy) and no mechanical movement. According to thermal dynamic analysis, the theoretical efficiency is as high as 80%, meaning it has great technical potential;
- Solar radiation is everywhere and solar energy is limitless; it is not confined to any region;
- Silicon material resources are virtually limitless;
- PV electricity generation is environmentally friendly - it does not generate any waste materials including green-house and other poisonous gases;
- PV electricity generation does not require cooling water, so it can be installed in desert areas;
- PV electricity generation can be integrated conveniently into buildings, saving precious land resources;
- As PV systems have no moving mechanical parts, they do not generate any noise;
- PV systems are module based, so easy to install, move and scale up;
- PV electricity systems do not require human operation and have only very low maintenance requirements;
- PV systems are very reliable with lifetimes of more than 30 years.

2.5.2 *Energy Recovery Time* Calculation for PV Electricity Generation

Energy recovery time is of general concern to society. There is constant research and evaluation of this topic by both domestic and international research centers. Their research shows that PV electricity generation systems have high energy recovery rates; this is a most desirable property for sustainable energy development.

The definition of *energy recovery time* for a power generation system is: the amount of time required to recover an equivalent amount of energy as was used in manufacturing the system. The unit for *energy recovery time* is the *year*, and the smaller the number the better.

Also, *energy recovery time* is a dynamic concept. With PV application expanding, developments in the industry and technology improvements, *energy recovery times* are getting smaller. For example, the *energy recovery time* for crystalline silicon PV systems during the 1980s was 5 -10 years. This was reduced to 3-8 years in the1990s, at the beginning of this century it was further reduced to 2.5-6 years and currently it is 2 – 5 years. It is estimated to reduce to 1 -2 years in the future.

In general, the *energy recovery time* for poly-silicon and thin film PV systems is shorter than for mono-silicon systems. *Energy recovery time* is also related to the solar energy resources of different regions and the installation methods. Regions having better solar resources, and systems installed at optimized angles, will have better *energy recovery times*. Another important factor is grid connection. Grid-connected PV systems have shorter *energy recovery times* than stand-alone PV systems. According to research in Holland, USA and Switzerland, the *energy recovery time* for modern grid-connected PV systems time is 1.5- 6.9 years, much shorter than the lifetime of PV systems (>30 years). With industry development and technology advancement, the *energy recovery time* for crystalline silicon PV systems could be reduced to less than 1 year, while for thin film solar cells it could be even less. For instance, the *World Energy Institute* reported its investigations on 41 cities in 26 OECD nations. The best polycrystalline silicon PV system had an *energy recovery time* of 1.6 years (Australia) compared to 3.3 years in England. For vertical PV wall systems, the best *energy recovery time* was 2.7 years (Australia) compared to 4.7 years in Belgium. (IEA—PVPSTask10,May 2006).

The *Shanghai Electricity Institute* did similar investigation for cities in China. The best installed polysilicon PV systems had an *energy recovery time* of 1.57 years (Lasa) compared to 6.92 years in Chongqing.

The above data was published when silicon wafer thickness was 300μm. By 2007, through technology development, most silicon wafers had been reduced to 200μm thickness or less. This would mean a shorter *energy recovery time*.

2.5.3 Leading Role of PV Electricity Generation in the Future

World energy supply has been ranked as number one on the list of the world's ten worst problems (energy, water, food, environment, poverty, terrorism & war, illness, education, democracy and population). In 2006, the world's population reached 6.5 billion, energy demand was more than 14.5TW and daily energy consumption was 220 million BOE (*barrels of oil equivalent*). According to forecasts for the year 2050, the world's population will be 9-10 billion, energy demand will be 60TW and daily energy consumption will be as high as 450-900 million BOEs. In 2050, renewable energy will supply most energy demand. But global potential for hydro energy is only 4.6TW, of which the exploitable part is only 0.9TW, for wind energy it is only 2TW and for biomass energy it is only 3TW. However, the potential solar energy resource is 120,000TW, the exploitable fraction of which is as high as 600TW. Solar energy is the only reliable energy resource to satisfy future world energy demand.

Table 25: Energy Demand and Renewable Energy Sources (TW)

2004 world energy consumption	13 TW
2050 forecast energy consumption	30 TW
2100 forecast energy consumption	46 TW
Hydro potential	< 0.5 TW
Ocean energy（tide, wave, stream）potential	< 2 TW
Geothermal potential	12 TW
Wind potential	2-4 TW
Solar potential	120,000 TW

Source: DOE- department of energy in USA, office of science 2005.4

According to an *European Joint Research Center* (JRC) forecast, solar energy will be the main source of energy in the future: in 2030, renewable energy is predicted to be more than 30% of total energy consumption, and PV electricity generation will be greater than 10% of total electricity generation. In 2050, renewable energy is predicted to be more than 50% of total energy consumption, and PV electricity generation will be greater than 20% of total electricity generation. At the end of this century, renewable energy is predicted to be more than 80% of total energy consumption, solar energy (PV plus thermal) will be greater then 60% of all energy consumption and PV electricity generation will be greater than 60% of total electricity generation. Tables 25 and 26 demonstrate the strategic position of solar energy in the future.

Table 26: *European Joint Research Center* (JRC) energy forecast

Energy Type	Proportion of total energy (%)	
	2050 年	2100 年
Renewable Energy	~52	~86
Solar energy（PV＋thermal）	~28	~67
PV electricity generation	~24	~64

3 Current Status of the PV Industry in China

3.1 The PV Industry Supply Chain

The PV industry supply chain consists of silicon material manufacture, silicon ingot/wafer production, solar cell production, PV module packaging and PV electricity generation system installation (See Figure16). In this section, each step of the supply chain will be described in detail.

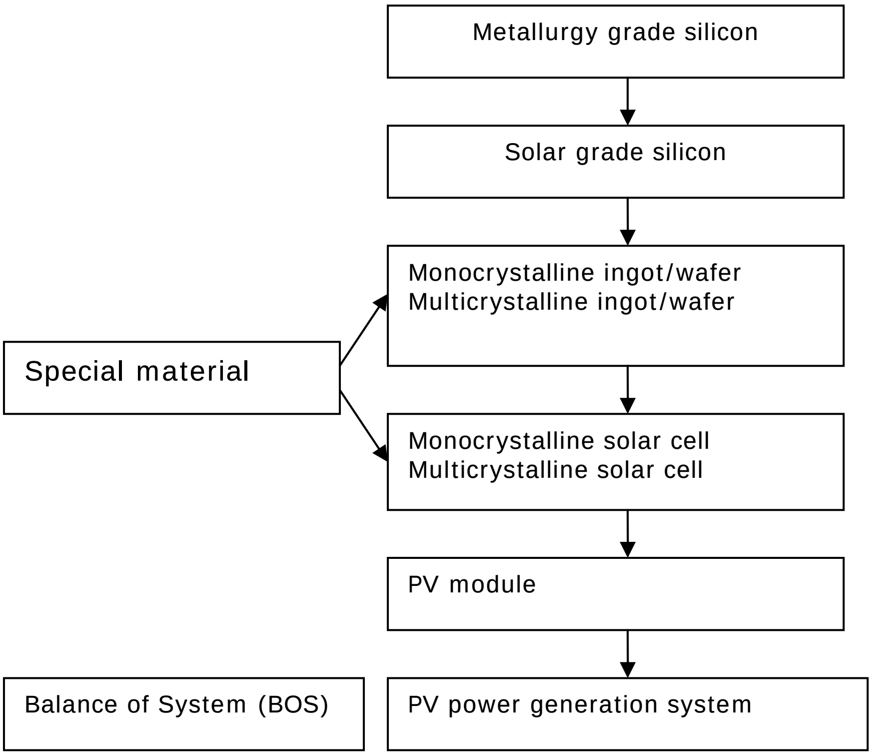


Figure 16: PV industry chain

3.2 Status of polycrystalline silicon feedstock industry

3.2.1 Global status

Silicon-based solar cells are still the main product in the PV market, occupying more than 91.25% of the total market in 2007. Therefore, production of the basic material - solar cell grade silicon - is a very important step in the PV industry supply chain.

Historically, solar grade silicon materials have come from surplus supplies of electronic grade silicon in the semiconductor industry. However, the PV industry's rapid growth of 40-60% over the last 10 years has been much faster than the semiconductor industry's 5-6% growth, meaning that the percentage of silicon feedstock used for the PV industry has greatly increased.

Today, pure polysilicon fabrication lines are on the scale of thousands of tonnes annually. The popular technologies are the Siemens production method and the fluidized-bed production method; the former technology provides 80% of the world's output, the latter technology 20%. In order to reduce the cost, various new methods for low cost solar cell grade silicon feedstock production have been researched but none has been commercialized.

Because polysilicon feedstock production is part of the chemical industry, with large production sizes, sophisticated technology, long periods for factory construction and huge investments (US$ 1 billion/thousand tonne/year plant capacity), polysilicon production growth has not kept up with the rate of growth of other steps in the PV supply chain. This has resulted in constant silicon feedstock shortage since 2004 and has created a bottle-neck for PV industry development. How to increase polysilicon production has been a hot topic for the PV industry. In 2006, the amount of polysilicon feedstock used by the PV industry became greater than the amount used in the electronic industry for the first time.

Because of the tense relation between supply and demand, the price of polycrystalline silicon feedstock has risen continually. In the period 2001-2003, the average sale price of polycrystalline silicon feedstock in the world was about US$40/kg for electronic grade, and about US$25/kg for solar grade. The price rose continually after 2004 to more than US$50/kg in the global market and more than US$200/kg in the black market. By the end of 2007, the price was more than US$350-400/kg in the global market. The rising price of silicon resulted in a rise in the price of solar cells and therefore reduced the rate of development of the PV industry .

Most polysilicon production comes from 10 companies in the world; their production from 2001 to 2006 is shown in table 27. Because of the rapid growth in the PV industry many of these factories are increasing their capacities; but in addition, many new companies are building polysilicon production lines. Forecast global production to 2010 is shown in table 28. Figure 17 shows the actual world polysilicon production capacity from 2004-2007 and that forecast for 2008-2015.

Table 27: World polysilicon production (ton/yr) from top 10 companies, 2001-2006.

Company	2001	2002	2003	2004	2005	2006
Hemlock(US)	5300	5100	5300	7000	7700	10000
Tokuyama(JP)	3500	3600	4000	4800	5600	6000
Wacker(DE)	3700	4000	4200	4600	5600	6600
Misubishi(US)	875	1065	1170	1210	1250	1250
Misubishi(JP)	1050	1300	1300	1400	1600	1600
Sumitomo(JP)	550	700	700	700	800	900
MEMC（US）	800	1500	1500	2200	2200	2600
MEMC（Italy）	1000	1000	1000	1000	1000	1000
Asimi(US)*	2800	2050	2100	2400	3000	6500
SGS(DE)*		150	1900	2200	2700	
Total	19,575	20,465	23,170	27,510	31,450	36,450

*: Asimi and SGS are REC's subsidiaries

Table 28: Planned polysilicon production capacity (tonnes/year), 2006-2010.

Company		2006	2007	2008	2009	2010
JP	Tokuyama	6000	6000	6000	8000	8400
	Misubishi	1600	1600	1800	1800	1800
	Solargiga Energy Holdings	900	1300	1400	1400	1400
	JFE	100	100	500～1000	500～1000	500～1000
	NSC	—	500	500	500	500
	M.setek	—	500	3000	3000	3000
	太阳硅公司（智索、新日铁、东邦钛）	—	—	100	100	100 15950
US	Hemlock	10000	14500	19000	27500	31750
	REC	5970	6670	13500	13500	13500
	MEMC	2600	2700	6700	6700	6700
	Misubishi（US）	1250	1500	1500	1500	1500
	Hoku	—	—	1500	2000	2000
Europe	Wacker (Germany)	6600	8000	10000	14500	14500
	MEMC（Italy）	1000	1000	1000	1000	1000
	JSSI（Germany）	—	—	850	850	850
	Elkem（Norway）	—	—	5000	5000	5000
	SilPro（France）	—	—	2500	2500	2500
Asia	China *	290	1130	3500	9000	18000
	DC（Korea）	—	—	3000	3000	3000
	Total	36,310	45,500	97,550	118,550	132,200

Table 29: Global polysilicon production forecast, 2007-2015. (thousand tonnes)

Year	2005	2006	2007	2008	2010	2011	2013	2015
Electronic Grade	18	19	20	21.5	24	25.6	28.7	32.3
Solar Grade	14	22	30	43.5	96	124.4	221.3	367.7
Total	32	41	50	65	120	150	250	400

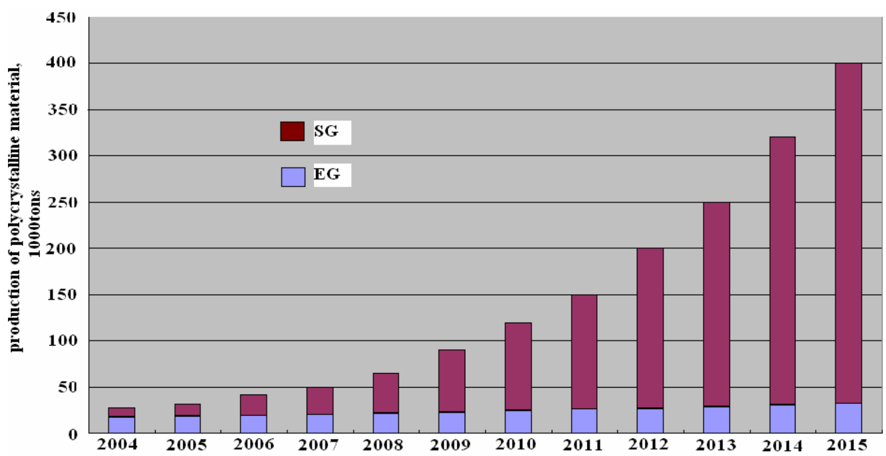


Figure: 17 Actual world polysilicon production capacity, 2004-2007, and forecast for 2008-2015.

3.2.2 Current Status of polysilicon production in China

In 2001, there were only 2 companies in China producing polysilicon (Emei Semiconductors and Luoyang High-Tech). Their combined annual production was only 80 tonnes - 0.6% of total global production. Luoyang High-Tech stopped polysilicon production in 2003; Emei Semiconductors continued to produce 60-70 tonnes per year. In 2005, Luoyang High-Tech introduced a 300 tonne per year production line using Siemens technology, and in 2006 Emei Semiconductors expanded its production capacity to 200 tonnes/year. Actual polysilicon production in China in 2006 was 390 tonnes (Luoyang High-Tech, 185 tonnes; Emei Semiconductors, 105 tonnes).

In 2007, Leshan XinGuang installed a 1,260 tonne/year production line and produced 155 tonnes; Luoyang High-Tech expanded its capacity from 300 tonnes/year to 1,000 tonne/year and produced 550 tonnes; Xuzhou Zhongneng installed a 1,500 tonne/year production line and produced 150 tonnes; Wuxi Zhongcai installed a 300 tonne/year production line and produced 55 tonnes; Emei Semiconductors produced 155 tonnes and Shanghai lingguang 20 tonnes. In total, China produced 1,130 tonnes of polysilicon in 2007 as shown in Figure 18 and Table 30. This annual production of polysilicon of more than 1,000 tonnes represented a turning point in the development of China's polysilicon industry.

Table 30: Polysilicon production capacity and actual output (tonnes) in China, 2005-2007.

Company	2005		2006		2007	
	Capacity	Output	Capacity	Output	Capacity	Output
Emei Semiconductors	100	80	100	105	200	155
LuoYang Zhonggui	300	—	300	185	1,000	520
leshan Xinguang	—	—	—	—	1,260	230
Xuzhong Zhongneng	—	—	—	—	1,500	150
Wuxi Zhongcai	—	—	—	—	300	55
Shanghai Lingguang					50	20
Total	400	80	400	290	4,310	1,130

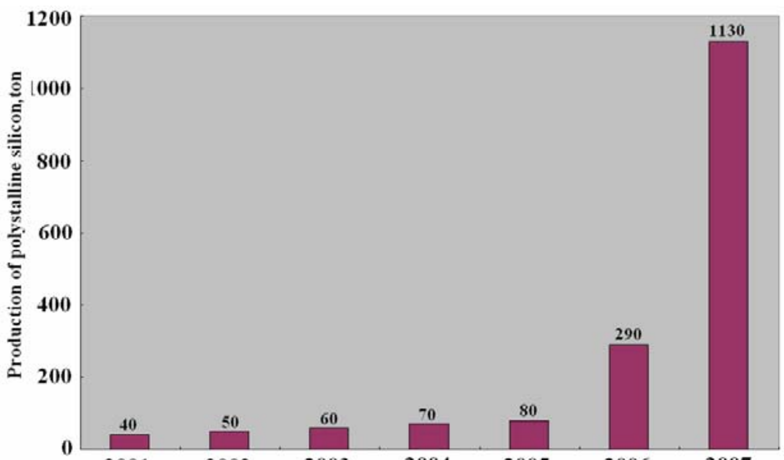


Figure 18: Actual production of polysilicon in China, 2001-2007.

Table 31 displays polysilicon supply, demand and shortage. It shows that polysilicon feedstock shortage continues to increase with the development of the PV industry, and reveals an intense, driving force for the development of the polysilicon industry in China.

Table 31: Polysilicon supply, demand and shortage in China, 2005-2007.

	2005	2006	2007
Polysilicon production（tonnes）	80	290	1,130
Polysilicon demand（tonnes）	1652	4,686	10,597
Polysilicon shortage（tonnes）	1572	4,396	9,467

Note: *Polysilicon consumption has been calculated as 12,11and 10 tonnes/ MWp, and actual silicon solar cell production at 137.7, 426 and 1059.7MWp for 2005, 2006 and 2007 respectively.*

3.2.3 Promising prospects for growth of the polysilicon industry in China

The polysilicon industry has developed rapidly since 2005 to meet global PV market demand. After Luoyang High-Tech, Leshan ZhongGui, Xuzhong Zhongneng and Emei Semicondutor established or expanded their production capacities, many companies seized the opportunity to participate in the development of the polysilicon industry and set up production lines to create a new wave of development. According to incomplete statistics, more than 50 companies are building, expanding or planning for polysilicon production lines. Table 28 lists finished, ongoing and planned polysilicon production lines from various companies. All of these companies have chosen Siemens technology. From this table, it can be seen that total production capacity is expected to exceed 100,000 tonnes/year by 2009 and130,000 tonnes/year by 2010. Market demand is stimulating R&D for new and more cost effective polysilicon manufacturing equipment. Industry, academics and research groups have come together to actively research and develop new methods and technologies. Science and technology departments, and the NDRC, will support projects to assist the development of the polysilicon industry. These are selected according to their level of technological innovation and development potential.

China's polysilicon production technology is still lagging behind other parts of the world. The technology being used in the industry is generally not robust - for most projects, the critical technology is waste gas recycling. Sichuan Xinguang has successfully resolved this issue and mastered the technology. This is a great example. With strong demand from the market for technical improvement, it is believed that China's polysilicon industry will make rapid and healthy progress.

3.3 Solar grade silicon ingot / wafer production

Solar grade silicon ingot/wafer production is the second step of the PV industry chain. It is also making rapid and healthy progress with the drive for this also coming from development of the PV market. There are more than 70 solar grade silicon ingot/wafer production companies (in this report, we combine silicon ingot and wafer production into one unit) in China today. Table 31 gives the major companies and their production capacities and actual outputs for solar grade monosilicon ingots. Total monosilicon ingot production in 2005, 2006 and 2007 was 2,216, 4,550 and 8,070 tonnes respectively. Table 32 gives the major companies and their production capacities and actual outputs for solar grade polysilicon ingots. Total polysilicon ingot production in 2005, 2006 and 2007 was 300, 1,120 and 3,740 tonnes respectively. Table 33 gives the combined total actual production, and production capacity, for solar grade monosilicon and polysilicon ingots. The total ingot yield in 2005, 2006 and 2007 was 2,516, 5,680 and 11,810 tonnes respectively. From tables 32 to 34 it can be seen that production capacity is much higher than actual output. There are two explanations for this:

1. newly installed equipment may not have been operating for the whole year; and,
2. the silicon feedstock shortage has been prevalent in all parts of the PV industry. It was therefore inevitable that equipment could not reach its full capacity in recent years.

Table 32: Monosilicon ingot production in China, 2005- 2007 (tonnes).

	Company	2005	2006	2007
		Output	Output	Output
1	Ningjin Jinglong	1126	1250	1500
2	Zhejiang renesola Co. Ltd	300	750	1100
3	Jinzhou Xinri silicon materials Co. Ltd	400	750	900
4	Yangzhong Huantai	—	350	900
5	Changzhou Trina solar Co. Ltd	—	300	680
6	Yangzhou Shunda Group	100	250	500
7	Shanghai COMTEC Ltd	—	30	450
8	Changzhou Eging photovoltaic technology Co. Ltd	80	200	300
9	Jiangyin Hairun	—	40	200
10	Beijing Langfang	—	100	150
11	Zhejiang Jiashan	—	—	120
12	Inner Mongolia Huhehaote	—	—	100
13	Zhejiang Kaihua	—	70	100
14	Shanghai wafer work PROP	—	30	80
15	Shanghai Songjiang	—	30	70
16	Xinjiang sunoasis Co. Ltd	—	—	60
17	Huzhong Xinyuangtai	—	—	50
18	Shanghai Jiujing	—	20	50
19	Tianjing Huano	—	20	40
	Others	210	360	710
	Total	2,216	4,550	8,070

Table 33: Polysilicon ingot production in China, 2006-2007 (tonnes).

Company	2005	2006	2007		
	Output	Output	Furnaces	Capacity	Output
LDK solar Co. Ltd	—	450	150	4000	2300
Tianwei Yingli New Energy Resources Co. Ltd	260	550	40	2000	1200
Changzhou Trina solar Co. Ltd	—	—	25	700	120
Jinggong P-D Shaoxing solar energy technology Co. Ltd	—	80	8	132	80
Zhejiang Sino-Italian Photovoltaic Co. Ltd	40	40	4	90	40
Total	300	1,120	227	6,922	3,740

Table 34: Total combined silicon (mono- and poly-) ingot production capacity and actual output, 2006-2007 (tonnes).

	2005 Output	2006 Output	2007	
			Output	Capacity
Monosilicon	2,216	4,550	8,070	14,400
Polysilicon	300	1,120	3,740	6,922
Total	2,516	5,680	11,810	21,322

In 2007, total crystalline silicon ingot production reached 11,810 tonnes, which is 108% more than the 5,680 tonnes produced in 2006 (polysilicon increased 231%, monosilicon 77%). Follow world trends, there has been a gradual transfer in solar grade silicon ingot production from monosilicon to polysilicon, indicating the maturity of silicon ingot production in China.

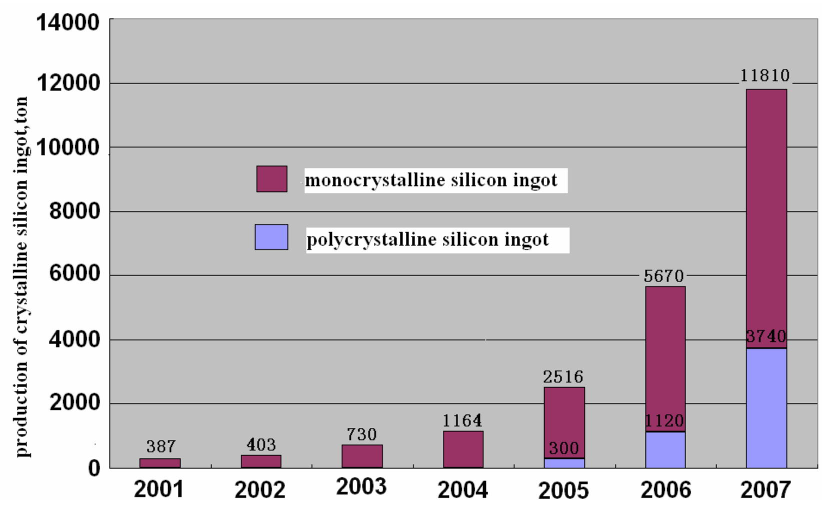


Figure 19: Production of solar grade silicon ingots in China, 2001-2007 (tonnes)

Table 35 shows the supply and demand relationship between silicon ingot and solar cell production. Allowing for statistical error, it can be said that supply and demand are balanced. In fact, with globalization and world market penetration, ingot/wafer sources are diversified compared to the situations before 2004. This balance of supply and demand indicates that the Chinese PV industry is on the right track for healthy development.

Table 35: Supply and demand relationship between silicon ingot and solar cell production.

year	2005	2006	2007
Production of crystalline silicon ingots(tonnes)	2,516	5,680	11,810
Potential solar cell production，MWp*	210	516	1,181
Actual solar cell production（Excluding polysilicon solar cell），MWp	137.7	426	1,059.7

Note: *Silicon consumption has been assumed as 12, 11 and 10 tonnes/MWp for 2005, 2006, 2007 respectively.

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

1) Rapid development. The annual average rate of increase in ingot production was more than 116% from 2004 to 2007.

2) High dependence on feedstock. Because there is inadequate polycrystalline silicon feedstock available domestically, China depends on imported materials. Because of insufficient supply and high mark-up in the international market for polycrystalline silicon feedstock, some domestic enterprises have been forced to operate below their production capacities.

3) The technologies are relatively mature, and the quality of production is comparable to that of foreign enterprises.

4) Production of mono-crystalline silicon still dominates 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 are expensive. For Cz-silicon, the necessary investment is less, the construction period is short and funds can be recovered quickly. Therefore, silicon feedstock manufacturers tend to choose a monocrystalline furnace that costs several hundred thousand Yuan over a casting furnace that costs several million Yuan. However, the rate of increase of polysilicon ingot manufacture surpassed that of monosilicon in 2007 (234% compared to 77%). The Jiangxi LDK Solar Hi-Tech Co. Ltd. has registered and begun construction of a polycrystalline silicon ingot and wafer manufacturing line that will have the largest production capacity in China. As domestic-made polycrystalline silicon casting furnaces become available, it is expected that the ratio of polysilicon ingots manufactured to total ingots manufactured will keep increasing to the world average.

3.4 Solar Cell Manufacture

3.4.1 Overview

Although impeded by the silicon feedstock shortage, China solar cell production still showed a fast growth rate in 2006 and 2007. Table 36 lists the production capacity and actual output of the major solar cell manufacturers in 2006 and 2007. Suntech kept the leading position for both years; its production output was 157.5MWp and 327MWp for 2006 and 2007, representing 35.9% and 30.1% of total Chinese production (438MWp and 1 088MWp).

Table 36: Solar cell production capacity and actual output in China, 2006-2007. (MWp/year)

	Company	2006年		2007年		
		Output	Rank	Production capacity	Output	Rank
1	Wuxi Suntech power Co. Ltd.	157.5	1	600	327	1
2	Tianwei yingli new energy resources Co. Ltd.	35	3	200	142.5	2
3	Hebei Jingao	25	5	200	113.2	3
5	Jiangsu Linyang Solarfun Co. Ltd.	25	5	200	88	4
4	CEEG	54	2	200	78	5
6	Canadian Solar Inc.	25	5	150	55	6
7	Ningbo Solar Electric Co. Ltd.	30	4	100	45	7
8	Changzhou Trina Solar Co. Ltd.	7.0	—	150	37	8
9	Jiangsu Junxin	14	7	50	35	9
10	Changzhong Yijing	—		60	30	10
11	Shanghai topsolar green energy Co. Ltd.	21	6	50	25	12
12	Wuxi Shangpin soalr	—		25	17	13
13	Shenzhen Topray Solar Co. Ltd.	c-2 a-6	8	c-5 a-15	c-2 a-8	14
14	Shanghai Chaori Solar Energy Science & Technology Co. Ltd.				10	15
15	Shanghai Solar Energy S&T Co. Ltd.	2		50	8	16
16	Zhejiang xiangrikui				8	16
17	Yunnan Tianda Photovoltaic Co. Ltd.	7	8	35	7	17
18	Shanshan Ulica Solar Science Co. Ltd.	3	11	25	7	17
19	Beijing Zhongqing	0.5		25	7	17
20	Shenzhen Jiawei Industries Co. Ltd.	—		40	5	18
Subtotal					5	
Others		24 （a-6）	—	441 (a-65)	33 (a-20.3)	—
Total		438 (a-12)	—	2814 （a-80）	1088 (a-28.3)	—

In 2006 and 2007, the rate of increase in solar cell production was very fast: 201% and 148% respectively. Figure 20 shows the increase in solar cell production from 2000 to 2007.

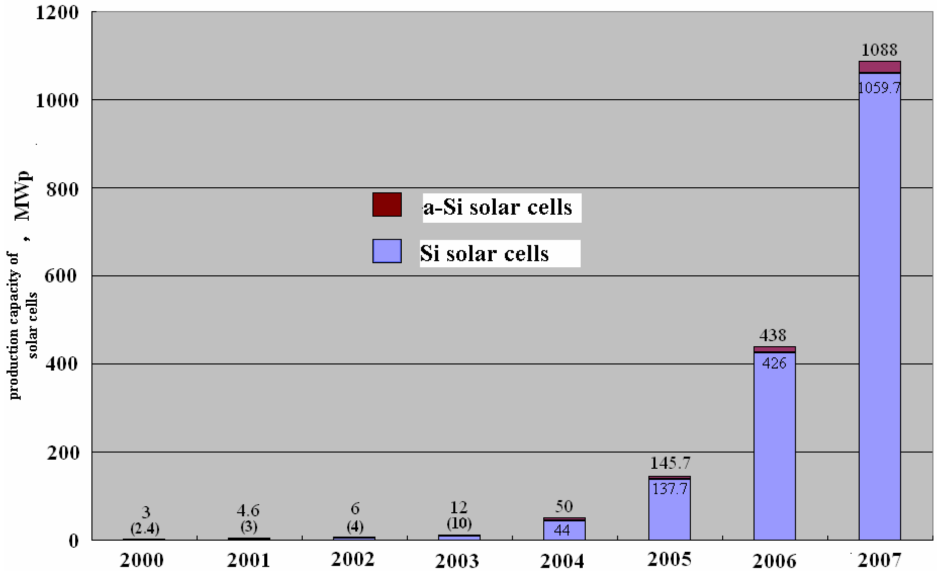


Figure 20: Solar cell production in China, 2000-2007.

Table 37 gives Taiwan's manufacturers and their production. It shows that the Taiwanese solar cell industry is also developing rapidly and is already one of the main production centres for solar cells in the world. The combined production output of mainland China and Taiwan was 1,560MWp in 2007, surpassing Japan's output of approximately 1,300MWp.

Table 37: Taiwanese solar cell production, 2005-2007.

Year	2005	2006	2007
Motech	60	102	196*
E-Tonne	28	32.5	72*
Del solar		20	45*
Gintech		15	55*
Total	88	169.5	368*

Source: PV News, Vol.27, No.3, March 2008.

3.4.2 China solar cell industry's position in the world

(1) World's largest solar cell provider

In 2006, China produced 438MWp of solar cells, 17.1% of the world total of 2,561.2MWp. This meant that China surpassed the United States to became the world's third largest manufacturer. In 2007 year, China's solar cell yield was 1,088MWp, surpassing Europe and Japan to became the world's largest manufacturer.

A listing from research data of all solar cell manufacturers in the world with production of 20MWp or more shows that there are 35 such companies as listed in table 38.

Among them, 14 come from China and 4 from Taiwan. This shows China's leading position in the world PV industry.

Table 38: World ranking of solar cell manufacturers, 2006 and 2007.

	Company	2006 年		2007 年	
		Output MWp	Rank	Output， MWp	Rank
1	Q-Cell(DE)	253.1	2	389.2	1
2	Sharp(JP)	434.4	1	363.0	2
3	Suntech(CH)	157.5	4	327	3
4	Kyocera(JP)	180	3	207	4
5	Firstsolar(US+DE)	60	13	207	4
6	Motech(TW)	102	7	196	5
7	Sanyo(JP)	155	5	165	6
8	SunPower(PH)	62.7	11	150.0	7
9	Baoding Yingli(CH)	35.0	17	142.5	8
10	Solar world(whole)	86.0	9	130.0	9
11	Misubishi(JP)	111	6	121	10
12	Jing-Ao(CH)	25.0	20	113.2	11
13	BP Solar(whole)	85.7	9	101.6	12
14	Solarfun(CH)	25.0	20	88.0	13
15	Isofoton（SP）	61	12	85	14
16	Schott Solar(DE＋US)	93.0	8	80.0	15
17	CEEG Nanjing(CH)	54.0	14	78.0	16
18	E-TON(TW)	32.5	17	72.0	17
19	ATS-Solar(CH)	25	20	55	18
20	Gintech(TW)	15.0	21	55.0	18
21	Ersolr(DE)	40	15	53	19
22	Ever-Q(DE)	15	21	49.8	20
23	United Solar(US)	28.0	19	48.0	21
24	Scancell(NW)	37.0	16	46.0	22
25	Ningbo Solar(CH)	30	18	45	23
26	Delsolar(TW)	20	20	45.0	23
27	Kaneka(JP)	28.0	19	40.0	24
28	Solland(NE)	18.0	21	37.0	25
29	Trina Solar(CH)	7.0		37.0	25
30	Sunways(DE)	30.0	18	36.0	26
31	Jiangsu Junxin(CH)	14		35	27
32	Photovoltaic(BE)	18.0		29.1	28
33	Microsol Inter.(UAE)	15.0		28.0	29
34	Jiaoda taiyang(CH)	21		25	30
35	Photowatt(F)	24		20	31

Source: PV News, 2008

(2) China's development of a high-level international PV industry.

As China entered the 21st century, its PV industry was experiencing healthy and rapid growth based on existing industry foundations. Important aspects of this success were co-operation, technology imports, manufacturing system imports and management improvement. China's PV industry was aiming to become international and modernized. At this time, the combination of industry development and capital market development greatly boosted China's PV market. Since 2002, the annual rate of increase of the industry had reached 191.3% and it has become a high level, international player in the PV industry. WuXi Suntech was the first to make an IPO in New York in 2005. In the last 2 years, 10 Chinese PV companies have made overseas IPOs with good results as shown in Table 39. Also, ShenJen Tuori successfully made an IPO in the domestic stock market. The sudden appearance of the China PV industry on the world stage was a PV industry development miracle.

Table 39: Chinese PV companies that have made overseas IPOs.

	Company	Date and Place
1	Wuxi Suntech Power Co. Ltd.	2005/12，New York
2	Zhejiang Renesola Co. Ltd.	2005 London，2007/7 transfer to New York
3	Canadian Solar Inc.	2006/11 NASDAQ
4	Jiangsu Linyang Solarfun Co. Ltd.	2006/12 NASDAQ
5	Changzhou Trina Solar Co. Ltd.	2006/12 NASDAQ
6	Jing-ao Solar Co. Ltd.	2006/12 NASDAQ
7	CEEG	2007/2 NASDAQ
8	Baoding Yingli	2007/4 New York
9	Jiangsu Junxin	2007/5 London
10	LDK Solar Co. Ltd.	2007/8 New York

3.4.3 Overview of Thin Film Solar Cell Development

China's a-Si solar cell industry has made steady progress since the introduction of the first single junction a-Si solar cell production line in the late 1980s in response to the exploding world PV market. In recent years, the a-Si solar cell industry has experienced fast growth. The silicon feedstock shortage in the last two years has especially boosted the development of the thin film solar cell industry. Since the introduction of the double junction a-Si solar cell 2.5MWp production line by Tianjing Jingneng in 2004, double junction a-Si solar cell production has also grown rapidly.

Table 40 gives China's major a-Si solar cell manufacturers and their production capabilities for 2006 and 2007. Figure 21 shows China's a-Si solar cell production since 2000. It shows that the production has grown dramatically since 2004.

Three factors have caused this rapid development of the a-Si thin film solar cell industry:

1. Rapid increase in the global PV market;
2. Thin film cell technology has matured;
3. Solar grade silicon feedstock shortage.

Table 40: China's major a-Si solar cell manufacturers and their production capabilities (MWp).

	Company	2006 Output	2007 Output
1	Shenzhen Topray Solar Co. Ltd.	6	8
2	Shenzhen Trony Science & Technology Development Co. Ltd.	2	4
3	Beijing Shihua	—	1
4	Tianjing Jingneng Solar Cell Co. Ltd.	1.2	2
5	Fuzhou Jintaiyang	—	2
6	Shenzhen Riyuehuan	1	1
7	Zhejiang Fusheng	—	1
8	Shenzheng Hengyang	—	1
9	Haerbin Gerui	—	1
10	Heilongjiang Hake New Energy Co. Ltd.	1	1
	Others	0.8	6.3
Total合计		12	28.3

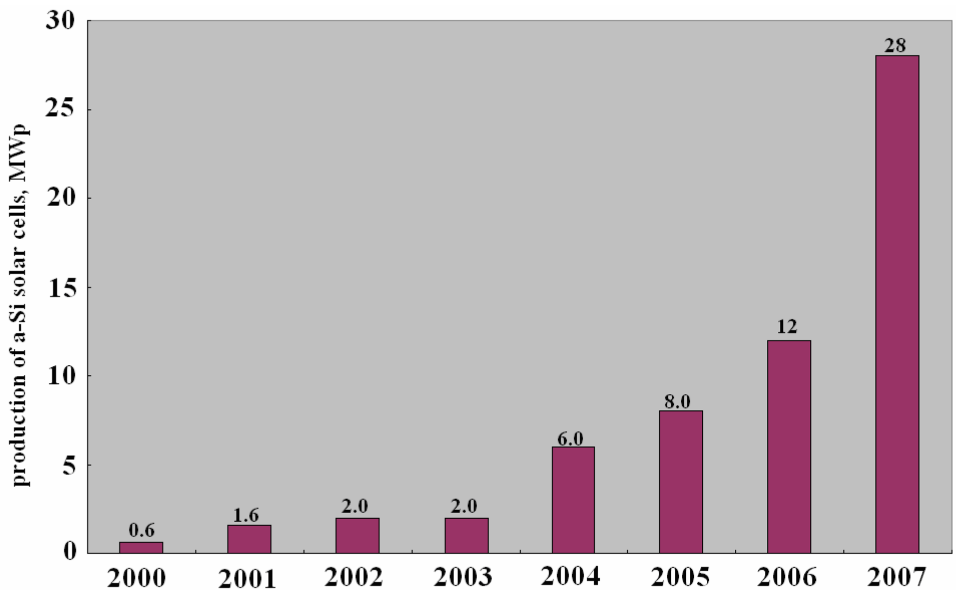


Figure 21: China's a-Si solar cell production, 2000-2007.

China's a-Si solar cell production was 12MWp and 28.3MWp in 2006 and 2007. China's thin film production capability increased by 80MWp in 2007. Companies like Suntech Electricity and Hebei Xinao are constructing more advanced a-Si/uc-Si solar cell production lines of up to 50MWp capacity. These production lines will elevate China's thin film industry to a new technology level.

Currently, a-Si solar cells are attracting attention because of their low cost, good appearance and good low light properties. However, they still face challenges like low efficiency, efficiency decay, short lifetime compared to crystalline silicon solar cells and low market acknowledgement. However, thin film manufacturing technology is still improving and the equipment is developing rapidly. Initial investment is much higher, and therefore so is the investment risk, than for crystalline silicon cell production lines. Therefore an investment in a-Si solar cell production requires thorough research, understanding and careful analysis.

3.5 Module Packaging Industry

3.5.1 Module Packaging Industry Overview

Only after packaging can solar cells be used commercially. Packaging provides basic protection for solar cells and ensures they perform to their lifetime potential. Packaging is an important step in the PV industry chain. Because the threshold of technology and funding is low, a module packaging line requires relatively less investment and a shorter construction period than other parts of the PV production chain and is thus suitable for small business investors. Companies that have solar cell production lines generally also have module packaging lines. According to statistics, there are more than 200 module packaging enterprises in China, with an annual packaging capacity of around 3,800MW_P. The 30 largest packaging enterprises account for more than 87% of total packaging capacity. Table 41 lists these 30 enterprises and their actual output for 2006 and 2007. There are a lot of small businesses specialized in packaging, but they are overall operating well below capacity.

Table 41: Thirty largest module packaging enterprises in China and their actual output, 2006 and 2007. (MWp)

序号	Company	2006	2007
1	Wuxi Suntech power Co. Ltd.	150	364
2	Tianwei Ying-li New Energy Resources Co. Ltd.	55	150
3	Jing-ao Solar Co. Ltd.	30	130
4	Shenzhen Jiawei Industries Co. Ltd.	45	120
5	Jiangsu Linyang Solarfun Co. Ltd.	45	82
6	Canadian Solar Inc.	25	82
7	Changzhou Trina Solar Co. Ltd.	30	80
8	CEEG	30	80
9	Ningbo Solar electric Co. Ltd.	40	70
11	Wuxi Shangpin Solar	25	50
10	Shanghai Hangtian-keji	50	50
12	Yunnan Tianda Photovoltaic Co. Ltd.	7	30
13	Shanghai Topsolar Green Energy Co. Ltd.	20	30
14	Kyocera (Tianjing) Solar Energy Co. Ltd.	10	25
15	Zhejiang Xiangrikui	5	25
16	Wuxi Erquan	5	20
17	Changzhou Yijing	—	20
18	Jiangsu Zhongsheng	—	15
19	Wuhan Rixin	10	15

20	BP Jianyang	10	15
21	Beijing Habo	10	12
22	Wuxi Guofei	8	10
23	Dongguan Huayuan	5	10
24	Xiamen Jumao	5	10
25	Shandong Dongying	5	10
26	Shanghai Chaori	5	10
27	Jiangsu Shunda	5	10
28	Jiangyin Junxin	5	8
29	Beijing Zhongqing	—	7
30	Shanshan Ulica	3	7
	Others	78	150
Total 合计		721	1,717

China's PV module production was 721MWp and 1,717MWp in 2006 and 2007, while solar cell production was 438MWp and 1,088MWp in the same period. This means that 283MWp and 629MWp of solar cells were imported in 2006 and 2007. The reason for this is that module packaging is a relatively labor-intense step in the PV industry chain, and the labor cost in China is relatively low. Because module packaging capacity is much greater in China than solar cell production capacity, along with the globalization of economies, foreign solar cells are being packaged in China.

For example, the 2007 production for solar cells from Q-Cells in Germany was 389.2 MWp, making it the world's largest solar cell manufacturer in that year. Q-Cells focuses only on solar cell manufacture, and sends its products to others for packaging. This is a very common work partition in the global PV industry chain. China's packaging capability is more competitive than in most other countries.

3.5.2 PV Module Cost Analysis, 2006 and 2007.

Crystalline silicon solar cell module prices in 2006 were less than in early 2005; from an average of US$4.05/Wp to an average of US$3.60/Wp. Since most Chinese PV modules are for export, the PV module price in China followed this trend. Domestic price reduced from 38Yuan/Wp in early 2005 to 32Yuan/Wp at the end of 2007.

Table 42 and Figure 22 show the price composition of a solar cell module made in 2007:

- Polysilicon feedstock: Spot price, US$200–250 /Kg, (average US$220 /Kg); Long-term contract price, US$50 – 60 /Kg Calculated on the basis of 9.3g of silicon/Wp, every kilogram of silicon feedstock would produce 107.5Wp of solar cells at a cost of US$ 2.05/Wp (spot price) or US$0.47 – 0.56 /Wp (long-term contract price);
- Crystal silicon wafer: 125x125 wafer price is US$6 /wafer; with 2.4Wp/wafer, this is equal to US$2.5 /Wp;

- Solar cell: US$3.0 – 3.1 /Wp;
- PV module: US$3.6 – 3.7/Wp.

Table 42: Price break-down (US$ / Wp) of solar cell modules, 2007.

Steps		Polysilicon	Wafer	Solar Cell	PV module
Sale Price	Spot	2.05	2.5	3.05	3.65
	Contract	0.515	0.92	1.42	1.97
Increment	Spot	2.05	0.45	0.55	0.6
	Contract	0.515	0.405	0.50	0.55
Percentage of total cost（%）	Spot	56.2	12.3	15.1	16.4
	Contract	26.1	20.6	25.4	27.9

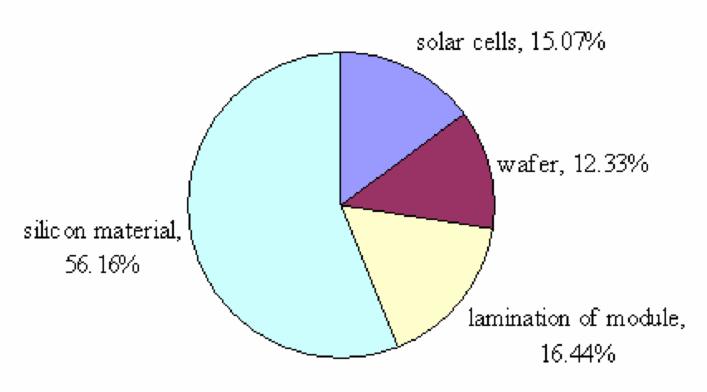


Figure 22: Price break-down (US$ / Wp) of solar cell modules, 2007.

Currently, world PV module prices generally vary in parallel with the silicon feedstock price because the silicon feedstock price comprises 56.2% of the PV module price (if the silicon is bought at the spot price). If the silicon feedstock is bought at the long-term contract price of US$50 – 60 /Kg, the PV module price is reduced to 1.97US$/Wp with 26.1% of the module price attributable to the cost of the silicon feedstock. When the PV module price is around US$2/Wp, and allowing s15% for tax and profit, the true PV module cost is around US$ 1.7 – 1.8 /Wp.

Obviously, as the silicon feedstock supply shortage is overcome, PV module price will be further reduced. If silicon feedstock price reduce to lower than US$25 /Kg, and there continue to be steady decreases in wafer thickness, and improvements in solar cell efficiency and other related technology improvements, the PV module price could reduce to US$1–1.5 /Wp. The cost of PV electricity generation would then be competitive with the cost of electricity generated by conventional means.

3.6 Balance-of-System Components – Inverter and Charge Controller Manufacture

PV balance-of-system (BOS) components are the components in a PV system other than the PV array. The main BOS components are the power controller, inverter, maximum power point tracker (MPPT), storage battery, power distribution system, bracket and cable and components for managing data collection, display, transmission and monitoring. Among these, the power controller/inverter is a core component, and the most important factor for system efficiency, reliability, lifespan and cost. Chinese-manufactured controllers/inverters have been developed and used in most off-grid PV systems and grid-connected systems up to 100–150KW. Some large scale grid-connected PV systems (>100KW) still use imported controller/inverters.

PV system controller/inverter manufacturers include: Hefei Yangguang, Beijing RiJia, Beijing Automation Research Center, Beijing HengDian, Beijing KenuoWeiye, ZhiChengGuangJun, Nanjing Guanhua, Beijing Jike and Nanzi Tonneghua, etc. Among these, Hefei YangGuang has 50MWp production capacity. The power of a single unit has reached 150KW. The products of these companies have been implemented with good operational results.

Other BOS components have also been developed in China and used satisfactorily in the domestic PV market.

3.7 Overview of PV Consumer Product Industry

At present, the main solar-powered consumer products include: street lamps, traffic signal lamps, garden lamps, signal lamps, calculators and toys etc. Because of demand from overseas markets, and the labor-intensive nature of the industry, many manufacturers of PV consumer products can be found in the Zhujiang Delta and the coastal regions, such as Fujian and Zhejiang. China has become the largest producer of PV consumer products in the world. The quantity of solar cells used annually for consumer products has reached 30MWp. Most products are exported overseas.

China has been making progress in the promotion of PV consumer products since 2006. The “New Village Light Up” program in Beijing has brought about the installation of 100,000 solar energy street and village lamps - the total investment has reached Yuan 0.6 billion. Other provinces and cities, such as Baoding, Shenzhen and Shandong, have followed Beijing’s example and have installed solar energy street lamps and LED lighting systems. From incomplete data, it appears that the total capacity of these installations reached 5MWp in 2007.

3.8 Status of equipment and specialized material manufacture for the PV industry

Major PV manufacturing equipment is required in every step of the PV industry chain, including: $SiHCL_3$ synthesis equipment, rectification towers, $SiHCL_3$ reducing furnaces, exhaust gas reclamation equipment for polysilicon manufacture’ monocrystalline and polycrystalline ingot furnaces’ wafer sawing equipment for crystalline silicon ingot/wafer manufacture’ cleaning equipment’ diffusion furnaces, PECVD systems, screen printing systems, baking furnaces, sintering furnaces for solar cell manufacture, laminating systems, laser scribing systems, module testers for the packaging step and controllers and inverters for PV electricity generation systems. The fast-growing global PV market has not only boosted China’s PV industry, but has also driven the development of manufacturing industries for equipment and specialized materials required in the PV production chain. This has resulted in the establishment of a completely new industry chain, which has not only changed China's traditional industrial structure, but has also brought social, economic and environmental benefits.

3.8.1 Polycrystalline Silicon Fabrication Equipment

China can produce, design and manufacture $SiHCL_3$ rectification towers and $SiHCL_3$ reducing furnaces. These are both produced by Emei Semiconductor and Luoyang Zhonggui. During the period 2008 - 2010, China will construct and put into production a large number of polysilicon production lines. Because of the rapid growth of the polysilicon industry, the design and manufacture of exhaust gas reclamation equipment and other related key equipment will also be accomplished.

3.8.2 Silicon Ingot/Wafer Fabrication Equipment

(1) Monosilicon ingot growth furnaces

China has a long history of manufacturing monosilicon ingot growth furnaces. The quantity produced has increased sharply in recent years because of the development of the PV market. Total sales value increased from Yuan 80 million in 2004 to Yuan 0.8 billion in 2007. Chinese-manufactured monosilicon ingot growth furnaces are popular because the quality is good enough to meet PV industry requirements yet the price is only one-third to one-half that of foreign products. There are several monosilicon ingot growth furnace manufacturers in China: JingYunTong(Beijing), JingKe (Xi'an), Shanghai Hanhong, Beijing JingYi, NingJinYangGuang, HuashengTianLong etc. Currently, there are 2,400 furnaces in use and most of them are made in China. In 2006 and 2007, sales volumes reached 400 and 800 units respectively. As well as satisfying the domestic market, some units are also being exported.

(2) Polysilicon Casting equipment

To satisfy market demand, the development of Chinese-manufactured polysilicon cast furnaces is speeding up. The present situation, of relying exclusively on imported equipment, is changing. Several enterprises, including the China Electronic Technology Co. 48 Unit and Jingyuntong, have already developed good quality products with capacities of 240–270 Kg and 400 – 450Kg, and have begun production and sales. In the next few years, they are expected to be more and more widely used in the domestic market.

(3) Development of a Chinese Dicing Saw

Currently, dicing saw equipment is all imported into China. To satisfy market demand, the development of a Chinese-manufactured dicing saw is speeding up, with several enterprises undertaking investigations. Shanghai Rijin is testing prototypes, and the product from a company in Gansu has passed certification. Hebei Ningjin is also doing development. It seems realistic that a Chinese-manufactured dicing saw will appear in the market very soon and will be competitive.

3.8.3 Solar Cell Fabrication Equipment

Solar cell manufacturing equipment includes wafer cleaning equipment, diffusion furnaces, PECVD systems, screen printing systems, baking and sintering furnaces and sorters.

Chinese-manufactured diffusion and baking furnaces, and PECVD systems, are available and have been adopted by major solar cell manufacturers. They have been developed by the China Electronic Technology Co. 48 Unit, Beijing, and 7stars Huachuang, etc. The main manufacturers of silicon wafer cleaning equipment are ShenZhen JieChuangJia, Beijing and 7stars, Huachuang. More than half of the solar cell production lines in China are using their products.

Semi-automatic screen printers, developed by the China Electronic Technology Co. 48 Unit, have been utilized substantially and automatic screen printers and sorters are under development. They are expected to enter the market within 1 – 2 years.

Solar cell sorters from the Xi'an Solar Energy Research Center, Shanghai Solar Energy Research Center and Qinhuangdao Boshuo can be used in small capacity production lines, and the China Electronic Technology Co. 48 Unit is developing an automatic sorter which it is expecting to put on the market within 1 – 2 years.

3.8.4 PV Module Packaging Equipment

PV module packaging equipment is made in China. Enterprises like Qinhuangdao Aoruite, Shanghai Shenke and Qinhuangdao Boshuo have laminating technology and supply over 90% of the demand from the domestic market, including from the top 30 solar cell manufacturers. Shanghai Shenke produces a large-scale auto packaging system and Qinhuangdao Aorite produces a series of lamination tools.

Laser scribing machine manufacturers include Wuhan Sangong, ShenZhen Dazu and Zhuhai Aomo. The Shanghai and Xi'an Solar Energy Research Centers produce PV module testers.

It is now possible for a whole solar cell production line to be built using Chinese-made products. Although these production lines are not fully automatic, their cost is much lower than production lines made in other countries.

3.8.5 Special Materials Manufacturing

Specialized materials for the PV industry include those used for monosilicon production, solar cell production and module packaging They include mixing materials, Ag, Al paste, PV glass, EVA (ethylene vinyl acetate) and TPT (a proprietary product used for PV module backsheets), etc.

Diffusion agent POCL3, and Al paste, which are used in solar cell production, are made in China. The possibility of producing Ag paste in China is under investigation.

Super-white low-Fe glass, used for PV module packaging, is made in China and has high quality. It supplies both domestic and overseas markets. The main manufacturers are DongGuan Xinyi, ShenZhen Nanpo, Shandong Jinjing and Henan JiaoZuo.

EVA production in China is still small and the quality is not comparable to that of imports. TFT is imported.

4 Status of the PV Market in China

4.1 Historical Evolution of China's PV Market

In China, 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 began in 1973. Limited by high price, the development of the PV market was quite slow. The terrestrial application of solar cells was at first limited to some small power systems, such as beacon lights, railway signal systems, weather stations on mountains, electric fences for grasslands, insect entrapping lights and DC solar lights with a power level from several Watts to a few tens of Watts. During the period of the 6th (1981-1985) and the 7th (1986-1990) "Five-Year Plans", the Chinese government started to support wider use of PV. The PV industry was promoted and PV was used in special industries and rural areas, for instance: solar-powered microwave relay stations, military communication systems, cathode protection for sluice gates and oil pipelines, carrier wave telephone systems in rural areas, small-scale solar household systems and power supply systems in villages.

In 2002, the SPDC started the "Township Electrification Program" (Song Dian Dao Xiang) which solved power supply problems for more than 700 townships in seven western provinces (Tibet, Xinjiang, Qinghai, Gansu, Inner Mongolia, Shanxi and Sichuan) through the use of PV and small-scale wind generators. The PV capacity totaled 15.3 MW. Since 2002, some other programs have been launched such as the "Brightness Program", "GEF/WB REDP" and the "Silk Road", which is a co-operative effort between the Netherlands and China. These programmes promoted PV power systems and have played an important role in satisfying the domestic electricity needs of peasants and herdsmen in remote western areas. China's PV market has kept pace with the times and has developed steadily in the past two decades. China's share of the global PV market was constant at about 1% before 2001. This share increased rapidly in 2002-2003 when the "Township Electrification Program" was launched, but decreased back to 0.5% and 0.3% in 2004 and 2005, respectively, when annual installations decreased to about 5 MWp. The introduction of the PV "Renewable Energy Laws" in 2006 did not have a significant effect on the development of the market, as had been hoped, because execution of the laws was largely ignored by local governments.

4.2 Current status of China's PV market

In general, China's PV market is making slow but steady progress. Total PV system capacity installed in 2007 was 20MWp (0.5% of the world's total) and accumulative installed capacity reached 100MWp (0.8% of the world's total). Table 43 and Figure 23 illustrate this development. The peak in annual installations in 2002 was due to the "Township Electrification Program". Although there was some small impact on the PV market from the introduction of the "Renewable Energy Law" in 2005, including from construction projects commissioned by local governments (such as off-grid PV systems for urban and rural areas and street lighting), total market growth was still very slow.

Table 43: Installed PV system capacity in China, annual and accumulative, 1976-2007. (MWp)

Year	1976	1980	1985	1990	1995	2000	2002	2004	2005	2006	2007
Annual Installation	0.0005	0.008	0.070	0.5	1.55	3.3	20.3	10	5	10	20
Accumulative Installation	0.0005	0.0165	0.2	1.78	6.63	19	45	65	70	80	100

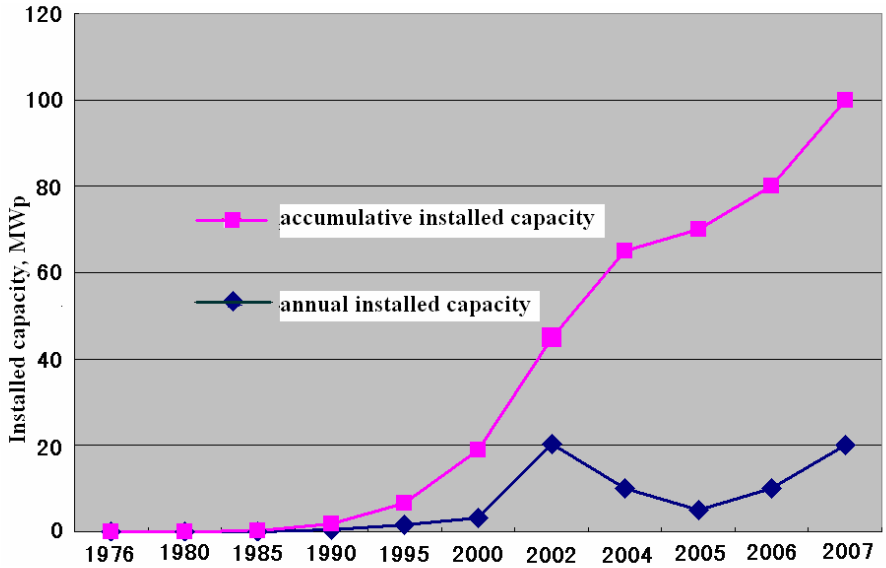


Figure 23: Installed PV system capacity in China, annual and accumulative, 1976-2007. (MWp)

4.3 PV applications in China

1) Telecommunication and industrial applications

Microwave relay stations, optical fiber communication systems, wireless communication stations, satellite communication and TV reception systems, telephone exchanges for rural areas, military communication systems, signal systems for railways and highways, power systems for beacons and navigation marks, weather or earthquake monitoring stations, hydrological observation systems, cathode protection for sluice gates, oil pipelines, etc.

2) Applications in rural and remote regions

Stand-alone village PV power supply systems, small-scale wind-PV hybrid power systems, solar household systems, solar lights, solar-powered pumps, community power systems in rural areas, etc.

3) Grid-connected PV power systems

Grid-connected PV power systems include building integration PV systems (BIPV) and large-scale desert PV power plants.

4) Solar energy lighting

Solar street lamps, solar yard lamps, solar lawn lamps, solar city sights, solar signals and marks, solar advertising lighting boxes;

5) Solar commodities and other applications

Solar fountains, solar battery chargers, solar clocks, solar watches and calculators; ventilators in cars; solar-powered automobiles; solar-powered yachts; solar toys, etc.

The total installation capacity of above application and market percentage by the end of 2006 are shown in table 44 and Fig. 24.

Table 44: 2006 PV application installation and market percentage

Market Partition	Accumulative Installation，MWp	Market Share，%
Rural electricity generation	33	41.25
Telecommunication and industry	27	33.75
PV products	16	20.0
（BIPV）	3.8	4.75
Terrestrial PV Power station	0.2	0.25
Total	80	100

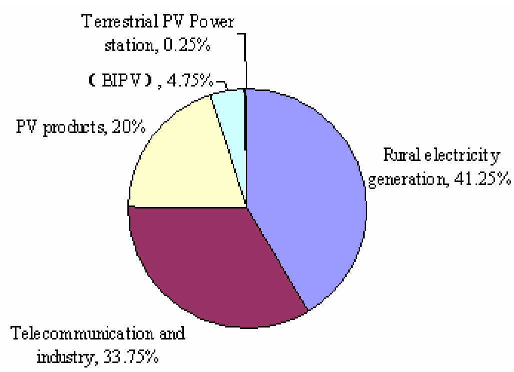


Fig. 24: application installation and market percentage

In all of these applications, about 53.8% belongs to the commercialized market (telecommunication and industrial applications and solar PV products), while the other 46.2% belongs to the market that needs support from the government and policies (rural electrification and grid-connected PV power generation). Only 5% are grid connected application (BIPV and ground PV power station), 95% are off grid applications. Annual installation in 2007 is 20MWp, accumulative installation capacity is 100MWp as shown in table 45. among them 17.7MWp (88.5%) are independent PV application, 2.3MWp (11.5%) are grid connected PV systems. In sharp contrast, world accumulative grid-connected PV application is 9.5GWp, about 79% of total PV market (12.3GWp), especially in Eroupe, in 2006, 2007 the ratio is as high as 99%. This sharp difference reflect not only Chinese uniquness, but also the primitive understanding and application stage of PV system. It is in great need to improve education for the whole society to understand the importance of grid-connected PV system development.

Table 45: 2007 China PV system installation and market share

Applications		Installation Capacity，MWp	Market Share，%
Rural electricity generation (Include street lighting)		9	42
Telecommunication &industry		3	30
PV consumer products		6	22
Grid connected power station	Non-focus	1.7	6
	Low focus(Inner mongolia＋Shanghai)	0.3	
Total		20	100

Science and technology department has started 5 MWp scale grid-connected PV system installation demonstration projects for “Eleventh Five year” ”863” plan. These projects will demonstrate and promote the grid-connected PV electricity generation.

Enterprises have taken initiatives to push grid-connected PV electricity generation development. Before “feed in tariff” was put into place, private investment started construction of large scale grid-connected PV electricity generation system, like Shanghai Chongming island’s 1MWp rooftop grid-connected PV electricity generation system contracted by Linyang New Energy; 1.5MWp Five star hotel grid-connected PV electricity generation building by Baoding Yingli; 1.2MWp airport and office building grid-connected PV electricity generation system by Wuxi Shangde; 1.2MWp Culture park grid-connected PV electricity generation system by ShenZhen Xintiandi, etc. These projects will demonstrate and promote the grid-connected PV electricity generation in China.

Appendix 3 gives lists of pilot and demonstration PV electricity generation projects for reference.

4.4 Plan of Future Photo Voltaic Electricity Generation In China

4.4.1 Medium, Long term Planning of Renewable Energy Application

Renewable energy is clean energy and ultimate choice that satisfy needs for human society’s sustainable development. Currently PV electricity generation technology is matured with broad application prospects. It will gradually replace regular energy electricity generation system, contribute to economical, social and environmental development in next 20~30 years.

China government pays great attention to renewable energy development. In August 2007 NDRC published “Renewable Energy medium, Long term development Plan”, at March 3, 2008, published

"Renewable Energy Eleventh Five Year Plan", further specify the development roadmap. Renewable energy (include 50MW and smaller hydraulic power station) total utilization are 166 million tonnes of coal in 2005, 7.5% of total power consumption. Table 46 gives medium, long term and "Eleventh Five Year Plan" (2006-2010) renewable energy development planning, table 47 gives PV electricity generation plan. Accordingly, China PV electricity generation accumulative installation capacity will reach 250Wp in 250MWp, 1600MWp in 2020.

Table 46: China renewable energy development plan

Year		2004	2010	2020
Wind Electricity	Installation capacity （10MW）	76	500	3000
	Yield（TWh）	11.4	105	690
Bio Electricity	Installation capacity （10MW）	200	550	2000
	Yield（TWh）	51.8	212	835
PV Electricity （Include PV thermal）	Installation Capacity （10MWp）	6.5	30（5）	180（20）
	Yield（TWh）	0.845	3.9（0.65）	23.4(2.6)

Table 47: 2005-2020 China PV electricity generation plan, MWp

Year	2005	2006	2007	2008	2009	2010	2020
Annual Installation capacity	5	15	25	40	60	（90）	—
Accumulative Installation capacity	70	86	110	150	210	（250）	（1600）

4.4.2 China PV electricity generation market forecast

As major strategic renewable energy resources, China government will strongly support PV electricity generation development. According to China PV electricity generation medium, long term plan, table 48, 49, Fig. 25 and Fig. 26 give market forecast for China PV electricity generation application in 2010, 2020.

Table 48: 2010 China PV electricity generation market forecast

Market Partition	Accumulative Installation, MWp	Market Share %
Rural electricity generation	80	32
Telecommunication and industry	40	16
PV products	30	12
（BIPV）	50	20
Terrestrial PV Power station	50	20
Total	250	100

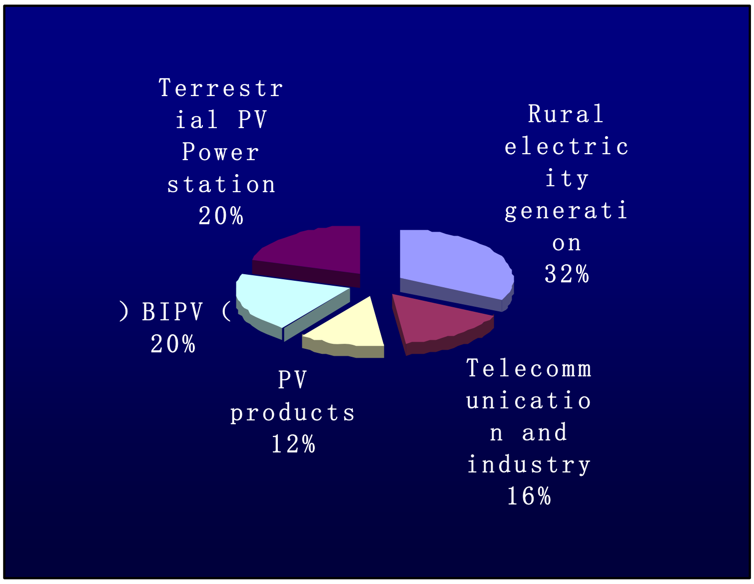


Fig. 25: 2010 China PV electricity generation market forecast

Table 49: 2020 China PV electricity generation market forecast

Market Partition	Accumulative Installation，MWp	Market Share，％
Rural electricity generation	200	12.5
Telecommunication and industry	100	6.25
PV products	100	6.25
（BIPV）	1000	62.5
Terrestrial PV Power station	200	12.5
Total	1600	100

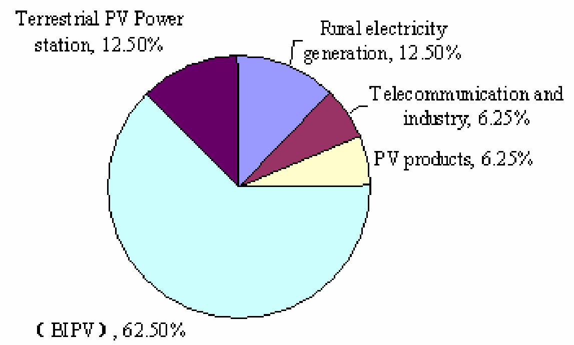


Fig. 26: 2020 China PV electricity generation market forecast

5 2006, 2007 Photovoltaic Industry Annual Sales Revenue, Employment Estimation

5.1 Sales revenue estimation

(1) Solar-grade silicon materials

In 2006, 290 tonnes of super-pure polycrystalline silicon materials were manufactured in China, and almost all of them were used in the PV industry. Assuming a price of 2000 Yuan/kg, this amounts to a sum of 580 million Yuan.

In 2007, 1130 tonnes of super-pure polycrystalline silicon materials were manufactured in China, and almost all of them were used in the PV industry. Assuming a price of 2000 Yuan/kg, this amounts to a sum of 2.26 billion Yuan.

(2) Silicon ingots/silicon wafers

In 2006, the yield of silicon ingots was 5670 tonnes (4550 tonnes of mono-crystalline silicon and 1120 tonnes of polycrystalline silicon). Assuming a price of 2400 Yuan/kg, this amounts to about 13.61 billion Yuan.

In 2007, the yield of silicon ingots was 11810 tonnes (8070 tonnes of mono-crystalline silicon and 3470 tonnes of polycrystalline silicon). Assuming a price of 2400 Yuan/kg, this amounts to about 28.34 billion Yuan.

(3) Solar cells/modules

In 2006, the production of solar cells/module was 721MWp. Assuming a price of 35 Yuan/Wp, the total sales were about 25.24 billion Yuan.

In 2007, the production of solar cells/module was 1717MWp. Assuming a price of 32 Yuan/Wp, the total sales were about 54.94 billion Yuan.

(4) PV Systems

In 2006, the PV engineering installations summed to 10 MWp. The total engineering cost was about 700 million Yuan, assuming an average cost of 70 million Yuan.

In 2007, the PV engineering installations summed to 20 MWp. The total engineering cost was about 700 million Yuan, assuming an average cost of 1.4 billion Yuan.

(5) PV application products such as solar garden lamps

The sum was about 1.5 billion Yuan in 2006.

The sum was about 2 billion Yuan in 2007.

(6) Equipment manufacturing industry

The sum was about 1.5 billion Yuan in 2006.

The sum was about 2 billion Yuan in 2007.

According to the calculations shown above, the total sales of the PV industry were about 40.93 billion Yuan in 2006, the total sales of the PV industry were about 88.24 billion Yuan in 2007. Assuming 20% pre-tax profits, the total pre-tax profits of China's PV industry were about 8.19 billion Yuan in 2006, 17.65 billion Yuan in 2007.
The issue of decreasing module price with increasing silicon feedstock price need to be discussed.

5.2 Employment estimation

Employment is the important index illustrates industries' social benefits. Table 50 gives employment estimation for PV industry chain in 2005 – 2007. It can be seen the fast employment growth parallel to PV industry growth, from 13.8 thousand in 2005 to 82.8 thousand in 2007. The economic and social benefit is remarkable.

Table 50: 2007 China PV industry employment estimation

Industry Chain	Employment		
	2005	**2006**	**2007**
Polycrystalline Silicon Production	1000	3600	7000
Silicon Ingot/Wafer	2360	7700	13000
Solar Cell	1500	4800	11000
PV Module	2650	9000	25000
System Installation &Service	2000	2600	3000
BOS（Inverter＋Storage Battery）	500	1000	1500
Special Materials（Glass，EVA，Ag, Al paste）	500	1800	2500
Lighting，Consumer Products	3000	8500	15000
R&D	300	500	800
Total	13810	39500	82800

Table 51 and Fig. 27 summarized 2005 – 2007 China PV industry sales revenue and employment, demonstrates that the PV industry is an industry with relatively high benefit.

2007 Sale income is 7 times of 2005, employment is 6 times of that in 2006. sales per person increase 16.8%, industry level and capability steady increasing, employment fast increasing, all sums up have significant economical and social benefit. At the same time, China export solar cell overseas, helps environment globally.

Table 51: 2005 – 2007 China PV industry sales revenue and employment

2005		2006		2007	
Sales（Billion）	Employment	Sales（Billion）	Employment	Sales（Billion）	Employment
12.8	13810	40.93	39500	88.24	82800

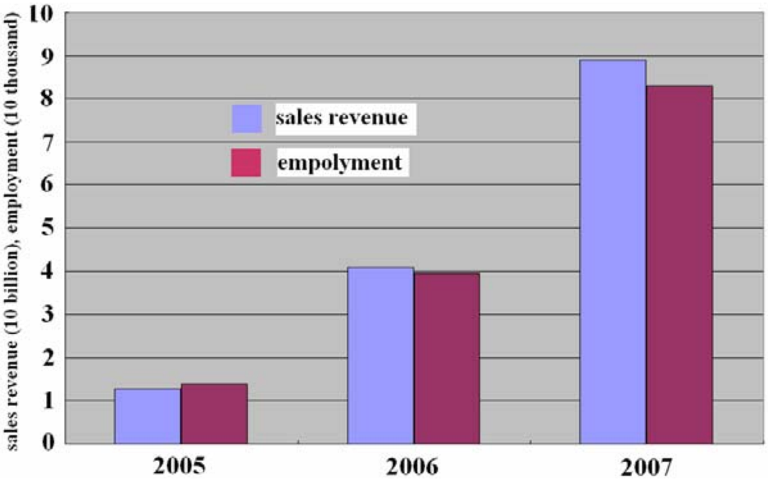


Fig. 27: 2005 – 2007 China PV industry sales revenue and employment

6 Technical Standards, Certification Systems and Quality Guarantee Systems for PV Products

6.1 Technical Standards for PV products

Technical standards for PV products are becoming more and more necessary for the development of the PV market. After China became a member of the WTO, and along with the rapid development of the PV industry, the PV technical standards are becoming more and more important in PV technical development, PV engineering, and PV commerce.

China has paid much attention to PV standardization, and the National Standardization Workgroup for Solar PV Energy Systems was founded in 1984. In 1987, the National Standardization Technical Committee for Solar PV Energy Systems (NSTC) was founded in Tianjin. The NSTC is a national standard technical work organization, and the standardization technique of the solar PV energy systems in China is under its jurisdiction. The secretariat under the council of the NSTC, affiliated with the 18th Research Institute of China Electronics Technology Group Corporation, is a standing body of the NSTC, and is in charge of dealing with the daily workings of the NSTC.

The industry of solar PV energy systems involves PV materials, solar cells, solar cell modules, solar cell arrays, PV testing systems, PV system controllers, PV system inverters, PV grid-connected systems, PV application systems (PV pumps, yard lamps, pharoses, etc.), etc. According to their constitution and characteristics, their standards can be divided into the following sorts: terminology, solar cell (non-concentrator modules), systems (off-grid systems, grid-connected systems), quality certification and appraisal, balance-of-system (BOS) equipment, concentrator solar power modules, and testing. The concentrated tasks of these various sorts are shown in Table 52.

Table 52 Standards system for China's solar PV power system

Type	Tasks
Terminology	To draft the standards for terminology
Solar cells	To draft the national standard and professional standard for solar cells
Un-concentrator solar power module	To draft the national standard and professional standard for un-concentrator solar power modules in terrestrial PV systems
System (grid-connected and off-grid system)	To draft the national standard and professional standard for the design, structure, installation, test, running, maintenance, and safety for PV systems' equipment
Quality certification and appraisal	To draft the national standard and professional standard for the quality certification and appraisal of the PV systems' equipment and module
BOS equipment	To draft the national standard and professional standard for BOS equipment in PV systems (storage battery, incharging controller, inverter, etc.)
Concentrator solar power module	To draft the national standard and professional standard for concentrator solar power modules in terrestrial PV systems
Testing	To draft the national standard and professional standard for the measuring methods and measuring equipment for solar cells, modules, and PV systems

There are 31 items of PV national standards and 10 terms of industry standards that have been published, and the names and serial numbers are given in Appendix; 2 terms of General standards, 20 terms of Solar cell and PV modules.

“PV components part 10: methods of linear testing”; “general standards for ground usage of silicon solar cell” and PV module certification part 2: experimental method”. 1 terms of PV BOS standards, already finished and waiting for published iterm is “technology requirement and testing methods for grid-connected PV system inverter”. 6 iterms for PV system standards, already finished and waiting for published iterms are: “technical standards for independent PV system”, “characteristics and parameters of independent PV system”, “Design Certification for independent PV system”, “Safety standards of grid-connected PV system”, “PV system grid-connection testing methods”. Already published but not formally accepted IECstandards are “Recommendations of small scale renewable energy system for rural electricity generation”, it includes 12 parts:

Part 1: Rural electricity system overview;

Part 2: Requirements and Usage conditions of rural electricity system;

Part 3: Project Initiation and Management;

Part 4: System Design and Selection;

Part 5: Safety Rule

Part 6: Certification, Operation, Sustaining and Replacement;

Part 7: Technical Standards: Generator;

Part 8: Technical Standards: Storage Battery and Controller;

Part 9: Technical Standards: System Integration;

Part10: Technical Standards: Energy Management;

Part 11: Technical Standards: Grid Connection Parameters;

Part 12: Other Topics.

In the 1990’s, the standard system of solar PV energy systems was formed in China, which was mainly based on standards formulated by ourselves. International exchange has been increasing, and the international IEC standards have been conforming to our national standards gradually. It can be said that Chinese PV standards meet the international ones well, and Chinese standards are basically the international general standards.

In recent years National standards committee encourages enterprises take tasks of standards compilation, enterprises can apply for standards formulation task, enterprises will supply standards drafts while supervised and approved by standards committee. By attracting enterprises actively participating standard formulation, the standard will be more realistic and have support from industry, also faster speed for standards establishment which helps to formulate the emerging new market, forster healthy development. The standards represents the industry and technology level of its country, enterprises which take responsibility to formulate standards should do it according to nation's interests, not their own interests; good standards can be recommand to apply for becoming international standards, so in the long run the PV products will follow China's standards.

6.2 PV Product Standards, Certification System and Quality Assurance System

A certification system has not been formally established in China at present. Compared with other well-rounded industries in China, the PV industry is a relatively small one, and does not involve important safety problems. Therefore it has not been necessary to require compulsory certification. But along with development of the PV application market, certification will be requested by both consumers and producers. There have been certification authorities that were authorized by the nation, and there are testing authorities that can conduct product tests as well as determine related qualifications according to the standards of concerned countries or the international standard. China has the hardware necessary to conduct PV product certification.

6.2.1 PV Testing and Certification Authorities in China

There are three major PV testing authorities in China: Tianjin Institute of Power Sources (the 18th Institute), Shanghai Institute of Space Power Sources (No. 811 Institute), the Quality Test Center of CAS Solar PV Power System, and Wind Power System.

In the Tianjin Institute of Power Sources, there are the Quality Supervising & Testing Center of Chemical-Physical Power Supply Products of the Ministry of Information Industry and the No. 3004 Calibration Lab of Metrology Station of the Tianjin National Defense Region. The testing center was the earliest one founded in China to perform PV testing, and it participated in the international comparison of solar cell standards held in 1993. It has provided reliable metrological and product testing services for space and civil institutions in China in the past three decades.

The Shanghai Institute of Space Power Sources is a subsidiary of the Shanghai Academy of Spaceflight Technology of China Aerospace Science & Technology Corporation, and it is an all-around institute of power sources. The institute has a research history of more than three decades, and it manufactures various kinds of PV products. In order to assure the quality of their products, a test laboratory was founded in the institute, and the laboratory has also tested products for other PV component manufacturers due to the extensive use of PV products. In 1990, the Shanghai Institute of Space Power Sources was authorized to be a Grade 3 metrology station by the Commission of Science Technology and Industry for National Defense.

Founded in 1999, the Quality Test Center of the CAS Solar PV Power System and Wind Power System was admitted by the CAS as a trusted third party for solar PV / wind power tests. The quality test center has three test laboratory branches: ① the Solar PV Component Test Laboratory (can test in accordance with GB/T 9535, i.e. IEC 61215); ② the Wind Power Component Test Laboratory; ③ and the Solar PV / Wind Power System Test Laboratory (built the first system test platform in China in accordance with IEC 62124). The test center built a strict quality control system in accordance with

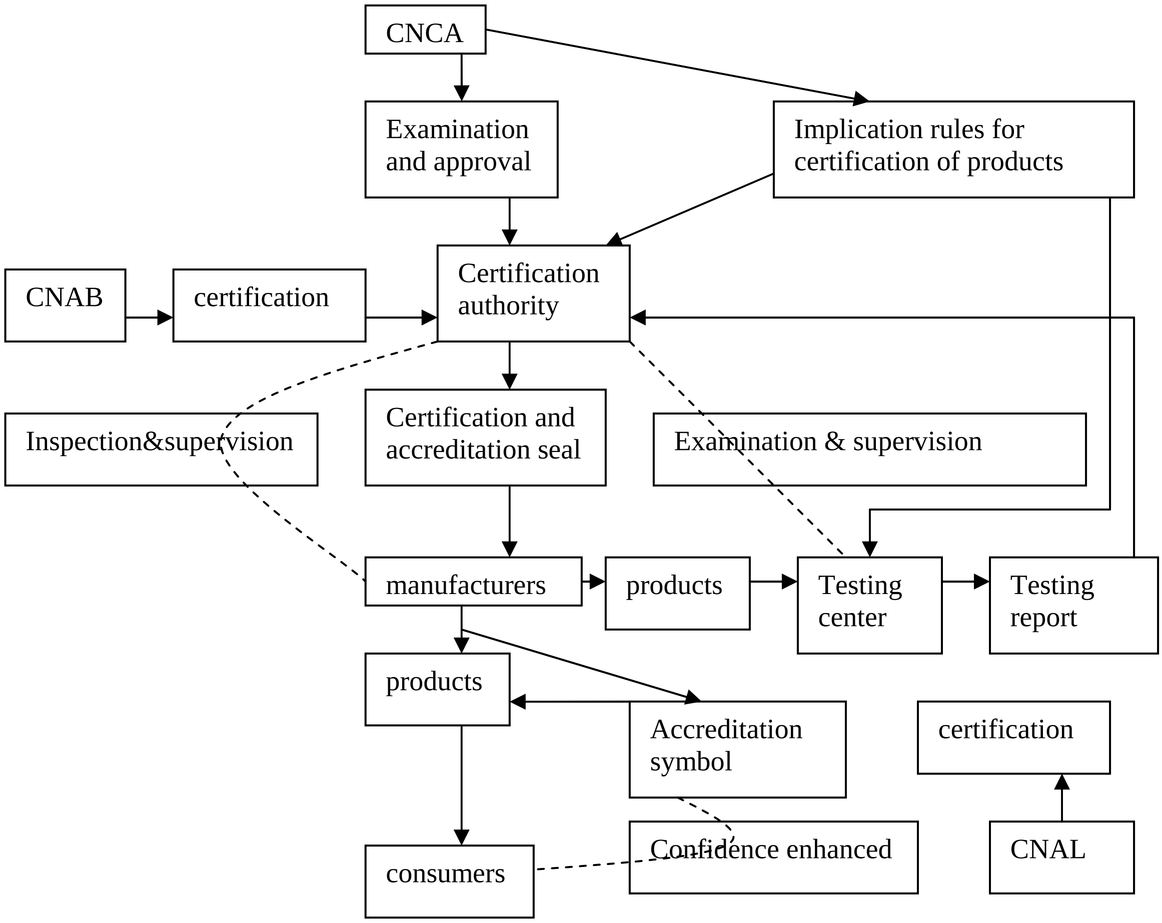
ISO/IEC 17025, and has been admitted by the China Metrology Accreditation (CMA) and the China National Accreditation Board for Laboratories (CNAL).

There is an authorized certification authority for the certification of renewable energy products, the China General Certification Center (CGC). As an authorized certification authority, it has begun the initial preparation for PV product certification, and established correlative certification documents and procedures.

In general China's testing level is not recognized by the world, To get international recogniztion is the main task for all testing centers.

6.2.2 Development Status of Certification of PV Products in China

In order to guarantee the healthy development of China's solar PV industry, the project of "Establishing China's Certification System for Solar Energy Photovoltaic Products" organized by NDRC/GEF/WB was started. The project was undertaken by the China General Certification Center (CGC). On August 1, 2006, the start-up meeting of the "Establishing China's Certification System for Solar Energy Photovoltaic Products" project & workshop on the implication rules was held by the CGC in Beijing. The Solar Energy Photovoltaic Products Certification Technical Committee was founded, and 20 experts from industrial associations, testing laboratories, and PV enterprises were engaged. Presently, technical specifications and implication rules, such as "Implication Rules for Certification of Stand-alone Photovoltaic Systems", "Implication Rules for Certification of Crystalline silicon Terrestrial Photovoltaic Module Products", "Implication Rules for Certification of Charging/Incharging Controllers and DC/AC Inverters", and "Technical Specifications for PV-use Valve Control Sealed Lead-Acid Storage Batteries", are being written.



CNCA China National Certification Association

CNAB China National Certification Bearu

CNAL China National Authorization Lab

Fig. 28 China Certification Management System

6.3 Issues of PV Standards, Testing, and Certification System in China

6.3.1 PV Standards

The IEC is accelerating the formulation of PV standards in accordance with the rapid development of the international PV market. As a member of the IEC, China has a large-scale PV industry. But none of the experts in China have joined the workgroups of the IEC to formulate international standards. This does not match the station of our PV industry. The major problem comes from funding, since it is a heavy burden for institutions to attend the two to three workshops that are held annually for each workgroup. In developed countries, the funds mainly come from government support. Now the NSTC for Solar PV Energy Systems has planned to appoint two experts to attend the workgroups of the IEC, and the funds come from REDP. However, the government should consider long-term support as soon as possible and appoint more experts to participate in the formulation of international PV standards. This way, the opinions of people in the Chinese PV industry can be represented in the discussion of international standards.

Also international PV standards' publication speed is faster, especially last year many new standards come up. But restricted by the limitation of total annual standards can be published, there is no single PV standard approved, even finished standards can not published. For example, standard "GB/T20047.1 – 2006 PV module safety qualification" both part 1, which adopted IEC's "61730-1 Ed. 1.0 Photovoltaic (PV) module safety qualification standard", and part 2 are finished but can not published. Which obstruct this standard's implementation. How to increase standards publishing speed is the major issues national standards committee should resolved as soon as possible.

Because of the standard number limitation of national standards committee, China PV standards committee will increase efforts of industry standard formualtion.

6.3.2 Testing and Certification of PV Products

The earliest application of our terrestrial PV products was to provide power for places where conventional electricity cannot be applied, such as lighthouses, communication relay stations, and cathodic protection for oil pipelines. But the price was high at that time, and a large batch of applications was not possible. Therefore, the tests were relatively simple. Since then, the requirements of product quality control have become stronger and stronger as the applications of PV products have increased. The first large-scale product quality test was for the pilot project of the "Brightness Program" carried out by the NDRC in 2000. During the operation of this project, the requirements for product quality were clarified for the first time. A technical expert group was formed, and a grading system for quality testing of PV products was written, which provided a favorable guarantee of the product quality for the owner enterprises. Along with the "Township Electrification Program" ("Song Dian Dao Xiang") in 2002 and the commercialization of PV products promoted by the REDP projects, the testing and quality supervision of PV products are being recognized more and more by owners and users.

At present, good quality and bad quality are intermingled in domestic PV products. During the operation of the pilot project of the "Brightness Program" in 2000, quality testing and control of PV products were performed for the first time. Many problems in product quality were found for domestic manufacturers when testing partly according to the IEC standards. This test rang drew attention to the quality problem of domestic manufacturers. Because the test standards adopted at that time were generally lower than the corresponding IEC standards, the test reflected the actual quality status of domestic manufacturers. However, most of the quality problems were found to be in the exportation and processing of the customers' own materials, and in ordinary encapsulation factories.

Because the majority of the PV market is abroad and the domestic testing and certification system lags behind international standards, domestic manufacturers are not willing to perform testing and certification in China. They prefer to send their products abroad. The testing and certification authorities abroad obtain brand benefits and economic benefits, and their stations are enhanced further. On the other hand, because Chinese testing and certification authorities do not have the ability to compete with them, the international certification authorities essentially have a monopoly on testing and certification, and Chinese manufacturers must accept both the price and the evaluation standard since they have no alternative. The government should provide funds to support the domestic testing authorities to perform international test comparisons. Then the credit standing of our testing authorities would rise gradually. This would set a stable basis for widely performing PV testing and certification in the future, and promote China’s ascent to become the largest PV producer as well as the largest market of PV applications.

Table 53 China PV system standards

ID	Serial number	Name	Replaced standard	Serial number of international standard	Name of international standard
1	GB/T2296-2001	Designation method of solar cells (photovoltaic device)	GB/T2296-1980		
2	GB/T2297-1989	Terminology for solar photovoltaic energy system	GB/T2297-1980		
3	GB/T6497-1986	The general rules of terrestrial solar cell calibration	SJ/T2197-1982		
4	GB/T11009-1989	Measuring methods of spectral response for solar cells			
5	GB/T11010-1989	Spectrum standard solar cell			
6	GB/T11011-1989	General rules for measurements of electrical characteristics of amorphous silicon solar cells			
7	SJ/T10459-1993	Measurement method for temperature coefficients of solar cells			
8	SJ/T10460-1993	Graphical symbols for solar photovoltaic energy systems			
9	SJ/T10698-1996	Amorphous silicon reference solar cells			
10	GB/T6495.1-1996	Photovoltaic devices - Part 1: Measurement of photovoltaic current-voltage characteristics	Part of GB/T6493-1986 Part of GB/T6495-1986	IEC60904-1 (1987)	Photovoltaic devices. Part 1: Measurement of photovoltaic current-voltage characteristics

11	GB/T6495.2-1996	Photovoltaic devices - Part 2: Requirements for reference solar cells	Part of GB/T6493-1986	IEC60904-2 (1989) IEC60904-2Amd.1 (1998)	Photovoltaic devices. Part 2: Requirements for reference solar cells
12	GB/T6495.3-1996	Photovoltaic devices - Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data	Part of GB/T6493-1986 Part of GB/T6495-1986	IEC60904-3 (1989)	Photovoltaic devices. Part 3: Measurement principles for terrestrial photovoltaic (PV) solar devices with reference spectral irradiance data
13	GB/T6495.4-1996	Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices	Part of GB/T6493-1986 Part of GB/T6495-1986	IEC60891 (1987) IEC60891Amd.1 (1992)	Procedures for temperature and irradiance corrections to measured I-V characteristics of crystalline silicon photovoltaic devices
14	GB/T6495.5-1997	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method		IEC60904-5 (1993)	Photovoltaic devices - Part 5: Determination of the equivalent cell temperature (ECT) of photovoltaic (PV) devices by the open-circuit voltage method
15	GB/T6495.8-2002	Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device		IEC60904-8 (1998)	Photovoltaic devices - Part 8: Measurement of spectral response of a photovoltaic (PV) device
16	GB/T12632-1990	General specifications of single silicon solar cells			
17	GB/T14008-1992	General specifications for sea-use solar cell modules			
18	SJ/T9550.29-1993	Terrestrial silicon solar cells - Quality grading standard			

19	SJ/T9550.30-1993	Terrestrial silicon solar cells and batteries - Quality grading standard			
20	GB/T9535-1998	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval	GB/T9535-1988 GB/T14007-1992 GB/T14009-1992	IEC61215 (1993)	Crystalline silicon terrestrial photovoltaic (PV) modules - Design qualification and type approval
21	SJ/T11209-1999	Photovoltaic devices - Part 6: Requirements for reference solar modules		IEC60904-6 (1994) IEC61904-6Amd.1 (1998)	Photovoltaic devices - Part 6: Requirements for reference solar modules
22	GB/T18912-2002	Salt mist corrosion testing of photovoltaic (PV) modules		IEC61701 (1995)	Salt mist corrosion testing of photovoltaic (PV) modules
23	GB/T18911-2002	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval		IEC61646 (1996)	Thin-film terrestrial photovoltaic (PV) modules - Design qualification and type approval
24	GB/T19394-2003	UV test for photovoltaic (PV) modules		IEC61345 (1998)	UV test for photovoltaic (PV) modules
25	SJ/T10173-1991	TDA75 single crystalline silicon solar cell			
26	GB/T18210-2000	Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics		IEC61829 (1995)	Crystalline silicon photovoltaic (PV) array - On-site measurement of I-V characteristics
27	SJ/T11127-1997	Overvoltage protection for photovoltaic (PV) power generating systems - Guide		IEC61173 (1992)	Overvoltage protection for photovoltaic (PV) power generating systems - Guide
28	GB/T18479-2001	Terrestrial photovoltaic (PV) power generating systems - General and guide		IEC61277 (1995)	Terrestrial photovoltaic (PV) power generating systems - General and guide

29	GB/T19393-2003	Rating of direct coupled photovoltaic (PV) pumping systems		IEC61702 (1995)	Rating of direct coupled photovoltaic (PV) pumping systems
30	GB/T11012-1989	Inspection procedures for electrical performance test equipments for solar cells			
31	GB/T12637-1990	General specification for solar simulator			
32	SJ/T10174-1991	Steady sunlight simulator for air-mass 1.5			
33	GB/T20046-2006	Photovoltaic (PV) systems - Characteristics of the utility interface		IEC61727 (1995)	Photovoltaic (PV) systems - Characteristics of the utility interface
34	GB/T20047.1-2006	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction		IEC 61730-1 Ed.1.0	Photovoltaic (PV) module safety qualification - Part 1: Requirements for construction
35	GB/T 19064-2003	Solar home system specifications and test procedure			

Note: GB represents national standard; SJ represents industry standard.

7 Laws and policies Promoting PV industry development in China

7.1 “Renewable Energy Law” and the provisional measures

In order to support renewable energy utilization, protect renewable energy electricity generation price management and cost-sharing, according to “Renewable Energy Law” and “Price and cost-sharing management pilot scheme”, follow German renewable energy electricity generation policy principle, China authorize “Feed in tariff” as PV market lever, support PV electricity generation industry development by reducing its high cost . Articles related to PV power are as follows:

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

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

Article 20 The excess between the expenses that power grid enterprises purchase renewable power on the basis of the price determined in Article 19 hereof and the expenses incurred in the purchase of average power price generated with conventional energy shall be shared in the selling price. Price authorities of the State Council shall prepare specific methods.

In 2007 State Electricity Regulatory Commission published 25th order “Full acquisition of enterprise grid renewable energy power control methods” (Sept. 1, 2007 going into effect), it emphasized on electricity grid enterprises must purchase renewable energy electricity with priority according to renewable energy law and provide grid connection service (cost of power grid connection system is included as additional cost and shared over whole power grid electricity price).

State council published "energy saving power generation scheduling approach" ("measures") jointly formulated by National Development and Reform Commission, State Administration of Environmental Protection, the State Electric Power Supervision Committee and the State Energy Office, it states under reliable operation, follow energy saving and economical principle, request electricity power grid enterprises schedule renewable energy power with following priority list:

1. Wind energy, solar energy, ocean energy, hydropower and other renewable energy generating units without the ability to regulate;

2. Hydraulic power energy, biomass, geothermal energy and other renewable energy generating units have the ability to regulate and garbage electricity generating units meet the requirements of environmental protection;

3. Nuclear power generating units;

4. Coal-fired cogeneration units which generate both heat and electricity; comprehensive utilization generation units utilized residue heat, residue gas, residual pressure, coal gangue;

5. Natural gas, coal gasification units;

6. Other coal-fired generating units, including the thermal load did not take the cogeneration unit;

7. Fuel generating units.

National Development and Reform Commission published "Temporary measures of additional income regulation of renewable energy power" in November, 2007. Renewable energy law states the purchase price difference between renewable energy electricity price and regular energy electricity price will be cost-shared in electricity sale price. In 2006, state electricity sale price was increased by 0.1 cent to subside the renewable energy electricity generation enterprises. In order to help these enterprises receive rebates promptly. "Temporary measures" has regulated more specific instructions.

"Temporary measures of additional income regulation of renewable energy power" gives precise definitions and instructions for renewable energy electricity additional income, additional taxation, taxation scope, electricity price additional quota trading and cost sharing plan. Renewable energy grid-connected system operation involve National Development and Reform Commission(NRDC), the State Electric Power Supervision Committee, local government, provincial electricity power grid enterprises, renewable energy power generation enterprises and supervision committees, etc.

Renewable energy independent electricity generation system operation also involve National Development and Reform Commission(NRDC), the State Electric Power Supervision Committee, provincial government and local development and reform Commission , provincial electricity power grid enterprises, renewable energy power generation enterprises, PV system operation company, local government and supervision committees, etc.

“Price and cost-sharing management pilot scheme” and "Temporary measures of additional income regulation of renewable energy power" state: The difference between operation cost of state commissioned or rebated public renewable energy independent electricity generation system and provincial average electricity sale price will be cost shared from renewable energy additional rebate. The surplus of Rebate for renewable energy electricity generation cost reduction can be traded within country.

7.2 Development status of the new “Feed-in Tariff” system

7.2.1 PV grid-connected electricity generation

Hundreds of PV grid-connected electricity generation system is operating in China now, installation capacity ranging from KW to 1MW, most of them are government commissioned application demonstration projects. From description in the previous section, policies and related regulations are authorized and established, but none projects is operated according to "Feed-in Tariff" method and none of them is invested and operated according to market commercial rule.

Most of PV grid-connected electricity generation system is still in experimenting stage. For safety and other concerns, PV generated electricity is not allowed transfer to main high voltage (10Kv) electricity power grid through power transformer, to realize true "Feed-in tariff" according to " cost and profit" direction, fully accept PV generated electricity, there are still great efforts need to be done by government and electricity companies.

At November 22, 2007, NRDC published "Notice of Large-Scale PV Power Station Construction Requirement" to 8 provinces in western regions, it requests these 8 provinces' desert grid-connected PV power station construction plan must be large than 5MW, also the feed-in tariff must be decided by market. The initiation of this project will effectively improve the PV market development in China.

7.2.2 Off-grid PV electricity generation

Even though it is clearly specified in renewable energy law and scheme off grid PV electricity power generation and operation cost will be cost shared over power grid electricity price, it is still far from reality. For example, during 2002- 2003 period, several hundreds of independent PV and Wind-PV electricity generation system had been installed in remote region of 7 provinces in northwest China due to "Township Electrification Program". After 5 years of operations, still no operation fund has been received; storage battery need to be replaced, electricity station operation and technical support still sustained by original building companies. How to enforce renewable energy law, collect and redistribute to cover the cost of PV electricity rebate to rural area PV electricity system's operation is an urgent issue for healthy development of PV industry.

8 Barriers to the Development of the PV Industry in China and Recommendations

8.1 Barriers

In recent years, the PV manufacturing industry in China has developed rapidly and attained many significant achievements. However, there are also many problems and obstacles to the further rapid development of the PV industry in China:

(1) The domestic PV market lags far behind the domestic PV manufacturing industry.

After the finish of the "Township Electrification Program" ("Song Dian Dao Xiang") of 2002-2003, the domestic PV market has grown very slowly, with annual installations of only about 5 - 20MW. But the PV manufacturing industry in China has continued to develop rapidly as it has been driven by the international market. In 2007, the production of solar cells was 1,200 MWp, and the production of PV modules was 1,800 MWp. But in this same year, only 20MWp of PV systems were installed in China. The PV market has fallen far behind the manufacturing industry, so that most of the solar cell modules made domestically are being exported. This situation impedes not only the sustainable development of energy supply in China, but also the healthy development of the PV industry. If the market continues to lag behind the industry for a long time, there will be severe effects. Such a situation needs to be considered carefully.

In 2005, the "Renewable Energy Law" was passed, and it has been in effect since January 1, 2006. The law ordains articles for a "feed-in tariff" and "cost-sharing in the whole network", and provides the best opportunity (and a sound legal foundation) for enhancing the domestic PV market. However, the detailed rules that are in place are not achieving the intended result of the "Renewable Energy Law" - they are not adequately promoting the uptake of renewable energy. This situation must be resolved as soon as possible.

Not only a favorable international market, but also a favorable domestic market, are needed for the development of the PV industry. The best means of developing the domestic market is to rigorously execute the "Renewable Energy Law". The development of the domestic market would not only provide new opportunities for the domestic manufacturing industry, but it would also significantly help to improve China's energy infrastructure and get electricity to people in remote regions that are currently without electricity.

(2) R&D and innovation are low

As PV enterprises in China expand, they are beginning to pay more attention to R&D. Many, including Wuxi Suntech, Jiangsu Linyang Solarfun and CEEG (Nanjing) PV-Tech, have founded their own R&D centers and have begun close co-operation with universities and research institutes domestically and abroad. Local governments are also paying more attention to R&D in the field of PV and are providing increasing amounts through matching investment schemes. The traditional situation in China of low investment in PV R&D, and the institutional separation of production, teaching and research, is vanishing.

However, because of a genaral lack of technical capability, and inadequate training of personnel, the level of R&D and innovation is still low. There are not enough technical personnel in enterprises. Key techniques and equipment depend on importation; and the task of digestion, absorption and innovation is arduous. In the face of intensive international competition, the acceleration of personnel training, and improving the level of innovation in China as soon as possible, are urgent and important strategic tasks.

The government should take full advantage of the opportunity afforded by the development of the PV industry and support it. In particular, the government should:

1. Respect the guideline of “enterprises being the subjects of innovation” and support increased investment in R&D and innovation in capable enterprises.
2. Follow the principle that “technical achievements should be tested by the market” in order to bring about tangible benefits from national investments.
3. Support fundamental and applied studies in the PV field so that China’s scientific research level in PV might gradually catch up with or even exceed that of the the most advanced countries.

8.2 Recommendations:

(1) Establish a Department of Energy (DOE).

A DOE should be established to oversee, manage and plan energy-related issues and to ensure that both energy saving and the increased application of renewable energy are given a high national priority in support of the goal of sustainable development. The “Renewable Energy Law of the People's Republic of China” should be unequivocally executed, especially the “feed-in tariff” and “cost sharing” schemes, so that the Law can be effective and play a significant role in promoting the development of PV power generation. Other rules and policies in the “Renewable Energy Law” should also be implemented, including tax reductions and exemptions and financial interest subsidies, etc.

(2) Develop a research-informed PV energy strategy

An expert team should be organized to study: the status of energy resources in the world and in China, global trends in the development of PV power generation and national development roadmaps from around the world for PV power generation. Based on these studies, a development roadmap and mid- and long-term development plans for PV power in China should be established to support the development of sustainable energy production and protection of the environment in China.

(3) Increase support for technology development

Advancement in technology is the main reason for the decreasing cost of PV power. Investment in science and technology should be increased to accelerate the advancement of PV technology in China and to decrease the cost of PV power. R&D on the key techniques for manufacturing solar-grade polycrystalline silicon should in particular be given more support to accelerate improvements in technical capability and scale of production in China.

(4) Establish a national R&D research organization

R&D in PV technology in China needs to be strengthened. A national R&D institution for renewable energy sources should be founded to provide direct scientific input for the development of renewable energy technology, and the renewable energy industry, in China.

(5) Establish a certification authority and certification system

A certification authority and certification system for PV techniques and products should be established to promote healthy development of the industry and market in China.

(6) Promote renewable energy education

More attention should be paid to the popularization of science in the nation as a whole in order to improve the knowledge of the people on renewable energy sources and the importance of further developing these. A course on renewable energy should be established in universities to train specialized personnel.

(7) Strengthen international co-operation

International co-operation should be promoted in the field of renewable energy, especially on laws governing renewable energy. Through co-operation, the statutory framework for renewable energy in China could be improved and the execution of the “Renewable Energy Law in China” could follow the example of other countries. Such co-operation would support not only the development of sustainable energy production in China but also the export potential of China’s PV industry.

Appendix 1

Major Events of China PV Industry Development (December 2005- December 2007)

1. On December 14, 2005, Wuxi Suntech Power Co. Ltd., became a listed company in New York Stock Exchange. From this beginning until early 2007, there are total 10 China PV companies successful IPO at oversea stock market with consistent excellent performance. It indicates China PV industry has entered world class PV industry and elevated to a new level.

2. In April 2006, the NDRC published the provisional measures on rules for “The Renewable Energy Law of the P. R. China”, which ordains that for wind power, a “bidding price” should be carried out; for biomass power, a “yardstick feed-in tariff + feed-in tariff of 0.25 Yuan” should be carried out; and for PV power, the principle of “one matter one solution” should be carried out.

3. In early August 2006, Wuxi Suntech purchased MSK, which is a Japanese professional PV module manufacturer. This was the first time that a Chinese PV enterprise, or any Chinese renewable energy enterprise, purchased a foreign PV enterprise. It can be regarded as another sign that the PV industry in China has reached a new status.

4. Great wall renewable energy conference (GWREF2006) was held in Beijing from October 24th to 27th, 2006.

5. The ninth China Solar Energy PV conference and exhibition was held in Chengdu from November 5^{th} to 9^{th}, 2006;

6. The first 1000 tonnes scale polysilicon production line from Sichuan Xinguang was commencement on February 26, 2007;

7. City of Baoding initiated “City of Solar Energy” Project on April 1^{st}, 2007. It requires new public and dwelling buildings without installation of solar energy lighting will not be certified.

8. National PV products certification system is formally announced, 12 companies received certification on March 13, 2007;

9. 24 pairs stick polysilicon reduction furnace R&D project (“863 project”) from Luoyang ZhongGui received approve from Department of science and technology on March 31, 2007;

10. National Development and Reform Commission (NRDC) published “renewable energy medium, long term development plan” on September 14, 2007;

11. The first International Solar Energy Conference (ISES Solar world congress 2007) was held in Beijing from September 18 to 21, 2007;

12. Department of Science and Technology and National Development and Reform Commission (NRDC) held joint new conference and announced the initiation of “renewable energy international cooperation plan” in Beijing on November 2, 2007.

13. Department of Science and Technology and National Development and Reform Commission (NRDC) and treasury ministry published plan for 5MWp PV electricity generation station construction in west area. This open the preclude for large scale on-grid PV power station construction

14. China (exclude China taiwa) PV solar cell production yield surpass European and japan, become world largest solar cell provider.

Appendix 2:

Finished and On-going Grid-Connected PV Power Systems in China

1. Pilot Demonstration Projects Of China PV Power System

Until now all demonstration independent and grid connected PV power stations are commissioned by Chinese government, foreign government and relevant international organizations. The execution of these projects positively promotes China PV products' quality control, PV technology PV market and PV industry development.

1.1 Pilot Demonstration Projects Of Off-Grid PV Power System

A brief list of independent PV power station Projects and their achievements in various

regions of China is summarized in this section.

(1) "Electricity: power of the rich helping the poor" project commissioned by Chinese government

Chinese government's "Electricity: power of the rich helping the poor" project was started in 1992, finished in 2000, solved electricity power supply shortage problem for counties in remote area formerly had little or no electricity power access.

In June, 1990, first 10KWp PV power station, designed and constructed by Beijing JiKe Co. with little road access, 4300m high altitude, extremely harsh weather conditions, was completed in Ali region' Geji County of tibet. Its successful construction and operation move forward China PV electricity generation application technology to a new stage.

In 1992 Jike Co. Constructed 20KWp PV power station in Cuoqin county of Ali region; in 1994 20Kwp PV power station was completed in Gaize county of Ali region; at the same year, another 30KWp PV power station was constructed by National Academy Electronic Research Center in Naqu region in Tibet.

In 1998 Jike Co. completed Gaize 80KWp PV power station expansion project, for the first time it utilized computer based monitoring system, engineers from Tibet and Beijing can monitor power station operation remotely. Also National Academy Electronic Research Center installed 100KWp PV power station in Anduo county of Naqu region.

All above PV power stations have been certified by ministry of electricity.

(2) National “Eighth Five Year Plan” key technology development project

On January, 1995, key technology development project of “Eighth Five Year Plan” – 30KW Wind/PV power station is completed in Jimo Xiaoguan island, Shandong. This power station consists of 5 5KW wind power units and 1 5KW PV power unit, build by National Academy Electronic Research Center.

(3) United Nations Educational, Scientific and Cultural Organization (UNESCO) Program

In June, 1996, jointly directed by UNESCO and China Science Association, “21^{st} century China Rural Solar Energy Demonstration School” – LingXi high school is completed in Mancheng county, Baoding, Hebei. Total school area are 1790m2, total number of faculty, staff and students are 582. Jike Co. contracted on 4KWp PV power station construction. Electricity from this PV power station partially satisfied school power usage demand. Since its operation started in June, 1996, its good performance brought social benefits, served as good example for demonstration of PV power station application.

4) Oil Pipe Cathode Protection Project

In 1996, seven 700Wp PV power station was constructed by Jike Co. deep into the desert in Xinqiang province, these power station provide electricity for oil, gas pipelines’ cathode protection.

(5) World Bank sponsored Schoolteacher service network Solar energy project

In 1999 thirteen solar energy powered elementary school was completed in Yunnan and Hainan provinces. Each school has a 1KWp PV power station, they provide electricity power for local schoolteacher’ service network, also local schoolboys and farmers can watch TV, open their visions. It serves as important demo for new energy application in education system.

(6) China government’s “Light Project”

From 1996 to 2000, central government and Xizhang, inner Mongolia and Gansu provinces executed “Light Project”, invested 40 million RMB to establish independent PV electricity generation system, wind energy power station, wind/PV power system, wind/PV/gas system. The projects helped local government’s organization, send electricity to poor regions, helped to utilize local natural resources, united different ethic groups, stabilized society, improve national defense and assist rural economy development.

(7) “PV Plan for Ali region” Project

In 2000, department of Science and technology, national electricity Co. jointly started “PV Plan for Ali region” Project. Total investment is 60 million RMB to install 190KWp PV electricity generation capacity, completed 38 PV power stations, 30 PV power water pump stations and 10 terrestrial satellite receiver stations. Supply 110000 PV power supply units to farmers in Ali region.

(8) Renewable Energy Development Project

National Development and Reform Commission(NRDC), the World Bank (WB) and the Global Environment Facility (GEF) commissioned Renewable Energy Development Project from 2002 to 2007, total installation capacity 10MWp, total 300000 to 350000 PV units, 25 million $ is used for PV electricity sale rebate.

(9) “Township Electrification Program”

NRDC started “Township Electrification Program” in 2002, until the end of 2005, there are 268 small hydraulic power station and 721 PV and Wind/PV power stations has been completed in 7 western provinces. 300000 families, 1.3 million people benefit from this project. Total investment 4.7 billion RMB, among them PV and Wind/PV units capacity are 15.5MWp, total investment 1.5 Billion RMB.

(10) "Silkroad Lighting" cooperate project – China & Holland

'Silkroad Lighting" cooperate project started in 2002, it is executed by Xingiang electronic energy co. and Shell Co. total investment 25 million Euros, Holland government donated 15 million euros. China sponsored 10 million euros. This project helped 78000 families, 300000 people get electricity access.

(11) New Energy Project in Inner Mongolia

Inner Mongolia started new energy project in 2001. total investment 225 million RMB, it is used to subside renewable energy power system application in rural area.

(12) West Solar Energy Cooperation Project (KFW) – China & Germany

From 2003 to 2005, China and German West Solar Energy Cooperation Project (KFW) was executed in Xinjiang, Gansu, Qinghai, Sichuan provinces. Total investment 26 millions from Germany, according to 7:3 ratio, China provided 24 million RMB in Xinjiang, 28 millions RMB in Qinghai, 25 millions RMB in Yunan.

(13) CIDA Solar Energy Rural Electricity Program

Supported by Canadian government, total investment 3.42 million Canada dollars, this program is to establish PV power station and provide relevant training in Inner Mongolia region.

(14) NEDO PV Program

Japanese government invested 38.53 millions to help establish PV module/solar cell testing center in Beijing and PV power stations in several provinces from 1998 to 2002.

(15) China PV electricity generation program in 2007

China PV market have expanded substantially in 2007, total numbers of programs started and completed in 2007 is more than 20. for example, Beijing 3000KWp solar energy street lighting program, 8000KWp west region mobile telecommunication program, 30KWp solar energy bookstore program in Qinghai and Gansu provinces, total installation capacity will reach 20MW.

Above PV electricity generation programs are only partial examples of China independent PV electricity programs, total investment of all these programs will sum up to more than 3 billion RMB.

1.2 Pilot Demonstration Projects Of Grid-Connected PV Power System

Chinese government has been very interested in grid-connected PV electricity generation technology. As early as "eighth five year plan", "ninth five year plan" period, government already organized resources to research on grid-connected PV electricity generation technology, including grid-connection technology, controller/inverter technology, etc.. During " tenth five year plan" period, Department of science and technology listed grid-connected PV electricity generation technology as major research direction, speeding up research on system design, key component manufacturing, PV application on building construction and completed many demonstration grid-connected PV power station. According to statistics, there are more than 60 PV grid-connected power stations which installation capacity is more than 5KWp. A brief description of typical grid-connected PV power stations is listed in this section, the rest are listed in Table 1.

(1) Shenzhen international gardening exhibition park 1MWp grid-connected PV power station

Invested by Shenzhen government, contracted to Beijing Kenuo Weiye, Shenzhen international gardening exhibition park 1MWp grid-connected PV power station was completed and connected to power grid in October, 2004. The successful completion of this project is a milestone of China PV grid connection power station, provide reference for large scale PV system design. This Power station is the first MWp level PV power station of China, also the largest grid connected PV power station in Asia. Total installation capacity 1000KWp, annual power yield 1 million KWh, equals fossil energy saving of 385 tonnes of coal, reduce dust pollution 4.8 tonnes, CO2 170 tonnes, SO2 7.68 tonnes. Electricity charge save 66640000 RMB annually, total savings in 20 years of operation reach 12.22 million RMB. This system makes exhibition park not only for gardening show, but also for demonstration of renewable energy applications, it serves to educate Shenzhen citizens, even china people environmental protection and energy saving concepts.

(2) Beijing Solar Energy Institute 100KW Grid-Connection PV Electricity Generation Program

Invested by Beijing NRDC, contracted by Beijing Solar Energy Institute, this project is finished and successfully connected to power grid in 2003.

(3) Capital Museum 300KWp Grid-Connection PV Electricity Generation Program

As the new landmark and major project of Beijing Olympic game, Beijing Capital Museum is designed to best illustrate the combination of architecture and art, construction and new technology implementation, present energy saving, environment friendly image of Beijing, 300KWp flexible PV modules is installed on 5000 square meters rooftop. This project is designed by national construction design institute, US Unisolar, US Dalson Co. constructed by Beijing Jike Co.. the flexible PV modules adopt US Satcon triple junction a-Si solar cell, directly glue to construction material with easy installation. This system elevate China PV power generation capacity for single building to world level. The new capital museum becomes the best image of energy saving, environment protection, high tech application modern museum, functions as the model of “sustainable energy development”.

(4) Yangbajing 100KWp Desert High-Voltage PV power station

Sponsored by Dept. of Science and Technology, NRDC and Tibet local government, Beijing Kenuo Weiye Co. begin construction of the first PV power station directly connected to high voltage power grid in Yangbajing in 2004, completed and successfully connected to power grid on August 3, 2005.

(5) Beijing Tianpu 50KWp Solar Energy Demonstration Program

Supported by Dept. of science and technology, Tianpu 50KWp BIPV Solar Energy Demonstration Program is completed by Bejing Kenuo Weiye Co. The uniqueness of this system is its combination of all types of solar cells, Polysilicon solar cell module, multi juctions a-Si thin film solar cell, CIS thin film solar cell. Successfully accomplished the combination of PV power generation and building construction.

(6) 30 PV power stations along Qingzang railroad

Qingzang railroad is the highest altitude railroad in the world, 30 PV power stations along the railroad is also the highest PV application in the world. Each PV power station installation capacity is 13KWp, at daytime, solar cell array will generate electricity, through inverter transfer to power grid, at night, electricity power grid will reversely charge storage battery for emergency backup. Each PV power station yield is estimated to 24000KWh each year, reduce CO2, SO2 discharge 9400Kg, save electricity fee 20000RMB (120000RMB according to Green electricity purchase by foreign standard).

(7) Beijing Olympic National Stadium 100KWp PV System

100KWp Beijing Olympic National Stadium 100KWp PV System consist of 2 subsystems, first part 90KWp using regular silicon solar cells installs on the rooftop, second part 10KWp use double glass PV module, installed on south wall replacing traditional glass wall, it is a major breakthrough of PV application on building constructions, it is true combination of PV system and building construction.

(8) Beijing Olympic Basketball Stadium 100KWp PV System, contracted by Beijing Jike, is expected completed by March, 2008. it is a good example of combination of city buildings and PV system, reflects "Technology Olympic, Green Olympic" concept.

(9) Wuxi Airport PV system

Wuxi airport 800KW PV system project contract is formally signed at January 17, 2007. it signified Wuxi airport is the first public construction utilize new energy power generation, to build energy saving, environment protection "green airport". This project is executed in 2 stages, the first stage invest 6.5 millions to build rooftop light belt by 75KW PV glass power station on terminal roof; the second stage a 725KWp power station will be installed on airport merchandize building rooftop. The whole project is estimated to be completed by the end of 2008. Wuxi airport PV system will adopt large volume of PV glass, this will propel China PV glass industry's development.

(10) Shanghai German School Solar Power System

Shanghai German School Solar Power System commissioned by SMA and SUNSET was completed at October 19, 2006. This is one of DENA's programs for global expansion of German school PV roof construction. Through this program, DENA wants to promote solar energy utilization around the world, demonstrate to the public the environmental concepts of no pollution renewable energy power generation, convey and popularize new energy concepts, especially PV utilization to young generations. At the same time advertise German's world leading PV technology, help German PV companies build up good relations with newly developed PV markets. In order to display the variety of PV power station monitoring system, a huge water proof display –Sunny Matrix by SMA is installed in the front of school, display to public PV system operation status.

Appendix Table 1 China Grid-Connected PV System

No	Contractor	Power	Location	Status
1	Beijing Rijia	10kWp	Beijing Rijia	Complete
2	Beijing Solar Energy Institute	10kWp	Beijing Solar Energy Institute	Complete
3	Beijing Jike, Hefei Industry Univ.	5kWp	Beijing Daxing district	Completed in 2000
4	Shenzhen	10kWp	Shenzhen	Complete
5	Beijing Jike, Hefei Industry Univ.	20kWp	Beijing Gulou area	Completed 2003
6	Nanka Univ,	4kWp	Nanka Univ	Complete
7	Xindelong	10kWp	BJ Jiaotong Univ.	Completed 2006
8	National Academy Electronic Research Center	50kWp	Beijing Daxing district	Completed 2003
9	Beijing Solar Energy Institute	100kWp	Beijing Solar Energy Institute office building	Complete
10	National Academy Electronic Research Center	1MWp	Shenzhen	Completed 2004,8
11	Tokyo Electricity	140kWp	Beijing street light center	Completed 2004,9
12	Unisolar、Beijing Jike	300kWp	Capital Museum	2005,12 Completed
13	Xingiang Energy Research Inst.	60kWp	Xingiang Energy Research Inst.	2005,3 Completed
14	National Academy Electronic Research Center	10kWp	Tibet Lasa	2004. 12. Completed
15	Huaneng	100kWp	Guangdong Nanao	2005 Completed
16	Kenuo Weiye	100kWp	Tibet yangbajing	2005. 8. Completed
17	SchentenSolar SMA	60kWp	Zhongguangcun software park	Completed
18	Huangming	20kWp	Huangming	Completed
19	Kenuo Weiye	43.2kWp	Beijing WV service center	2005. 10. Completed
20	Kenuo Weiye	24kWp	Linuo technology park	2006. 2. Completed
21	Beijing Jike、Xingiang Energy Research Inst.、China Railroad Co.	390kWp	30 PV power stations along qingzhang railroad	2006 Completed
22	Beijing Dongrui、BJ Automation Inst.	90kWp	Beijing traffic management center	2006,3 Completed
23	Beijing Dongrui、BJ Automation Inst.	80kWp	Fengtai baseball center	2006,8 Completed
24	Shanghai Solar Energy Tech.	100kWp	NRDC office building	2006 Completed
25	Qinghua Energy Research Inst.	60kWp	Qinghua Energy Research Inst.	2006 Completed
26	Beijing Jike、Information Dept. Post Standard Inst.	5 kWp	Information Dept. Post Standard Inst.	2006 Completed
27	ShenZhen United Energy	80kWp	20units BIPV	2006 Completed
28	Beijing Solar Energy Institute	56kWp	15 units BIPV	2006 Completed

29	Beijing Jike	44kWp	Beijing traffic center	2007 Completed
30	Kenuo Weiye	25 kWp	Hainan gas station	2007．1．Completed
31	JX	400 kWp focus	Shang flower dock	2007．100kWp Completed，300kWp constructing
32	Anhui Yingtian	205 kWp focus	Inner Mongolia Erdos	2007 Completed
33	Linyang、Shanghai Solar Energy、Shanghai Taiyang	1000kWp	Shanghai chongming island	2007 Completed
34	Kenuo Weiye	100kWp	Olympic national stadium	constructing
35	Beijing Jike	100kWp	Olympic basketball stadium	constructing
36	Shenzhen Ruihua	400kWp	Beijing south railway station BIPV	constructing
37	Suntech	800kWp	Wuxi Airport	2007．1．17．sing contract
38	Kenuo Weiye	65kWp	Olympic park	constructing，completion by 2008
39	Shanghai Shenneng	1000kWp	Shanghai Lingang	2007 constructing
40	Qinghai Energy Research Inst.	300kWp	NEDO	constructing
41	Baoding Yingli	1500kWp	Baoding	constructing
42	Shenzhen Xintianguang	1200kWp	Shenzhen longgang district	constructing
43	National Academy Electronic Research Center	1000kWp	Olympic park	Completion by 2009
44	Kenuo Weiye	1000kWp	Yangbajing	Completion by 2009
45	Beijing Jike、Gansu Energy Research Inst.、Hefei Yangguang	1000kWp	Gansu Wuwei	Completion by 2009
46	Shanghai Solar Energy	1000kWp	Shanghai BIPV	Completion by 2009
47	Nanjing Hehai Univ.	1000kWp	Low degree focus	Completion by 2009
48	Sichuan	1000kWp	High degree focus	Completion by 2009