PV MARKET AND INDUSTRY DEVELOPMENT IN CHINA
IMPACTS OF PV PROGRAMS AND TECHNOLOGY IMPROVEMENT

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Abstract: China is THE global runner-up in the PV field. This concerns PV market but even more PV industry development. Especially since 2004 the PV supply chain has developed explosively successful. A drawback is that the industry is orienting more and more towards export, and neglecting (partly due to shortage in modules and manpower) the home market to certain extends especially the market of rural applications.
The NDRC/World Bank/GEF China Renewable Energy Development Project (REDP) is 'running' from 2001 to 2006. The PV component is aiming at developing the rural market for PV (and small wind) in six north-western provinces.
The TI component encourages technology improvement that will lead to lower cost and better quality of components for PV and PV/wind systems. The in-official aim of the TI is also to give the Chinese industry a better chance at competing with western industries in the renewable energy market in general and the Chinese PV market.
China had several quality problems in the PV market around 2000, such as the mal functioning due to lacking quality of the PV module, of essential other components (esp. the controller) or due to slow service. By the REDP much attention was paid to how to improve quality in the Chinese market in the supply and service chain. REDP substantially affected the quality of PV components produced in China and the professionalizing of Chinese PV industry.
Around the year 2000 the NDRC/WB/GEF China REDP has also been crucial for the attention of the Chinese authorities and industry for PV. Now at the end of the China REDP new programs take over the guiding and trendsetting role, paving the way for China to be one of the top-3 countries in the global PV field before the year 2010.

Key Words: PV Market, PV Industry, China, Technology Improvement.

1 Introduction

In China the attention for PV has grown strongly. This can be seen both in the local PV markets but much more in the development of PV industry. Especially since 2004 a growth explosion can be seen, the end is not yet within view. The new companies are orienting towards export and less towards the market of rural applications. The development of PV is paralleled by stimulation programs by the Chinese national, provincial and sometimes municipal governments.

Before 2004 a special role in this development was plaid by the World Bank/GEF China Renewable Energy Development Project (REDP). The REDP is a cooperation between the Chinese Government, GEF (Global Environment Facility) and the World Bank. The project aims at reducing CO2 emission, slowing down the global climate change and improving the living standard of the people who have no access to electricity in remote areas. The project consists of three parts: Wind component, PV solar home system component and Technology Improvement Component (TIC).

The first two components are market development programs aiming at developing the rural electricity market for wind and PV in six north-western provinces. The third TI component encourages technology transformation and technology transfer. Support is provided to finance technology improvement activities, that will lead to lower cost and/or better quality of components for PV and PV/wind systems.

The REDP has been prepared from 1997-2001. The project's components are 'running' from 2001/2 to 2006 and open both for Chinese and for foreign industries. Together with Chinese pioneers from the first hour the REDP has been paving the way for the Chinese PV development and for new stimulation programs.

2 The China PV Market

2.1 Status RE 2005

Since 50 years China has been using small and micro hydro-power for the electrification of villages in rural areas. The accumulated installed capacity to date is 23,000 MW. The attention to RE in the past decade has resulted in about 500 MW of wind farms, 500 MW of biomass cogeneration and several other RE power plants with smaller capacities.

The attention to PV since the late nineties resulted in over 500,000 Solar Home Systems (SHS's) installed mainly in the six remote north-western provinces, and added to about another 300,000 existing small decentralized micro-wind (170,000) and micro-hydro systems (150,000).

2.2 PV Market 2005

The distribution of sales and installed capacity of PV in China is given in Figure 1 and Table 1.

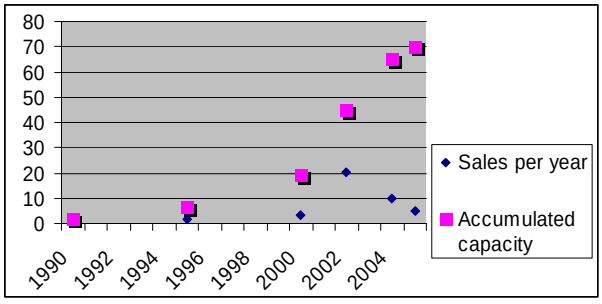

Figure 1a: Installed capacity/sales of PV in MWp per year
1b: Accumulated installed capacity of PV in MWp

Table 1: PV market development in China 1976-2005

Year	Annual Installed Capacity (kW)	Accumulative Installed Capacity (kW)
1976	0.5	0.5
1980	8	16.5
1985	70	200
1990	500	1780
1995	1550	6630
2000	3300	19000
2002	20300	45000
2004	10000	65000
2005	5000	70000

The national PV market in China is developing as follows:

- before 2000 the PV market was small with professional applications as telecom, being the largest market segment
- due to the REDP and the growing attention for village electrification with PV now (end of 2005) the internal PV market is dominated by rural applications of PV
- the rural PV market segment is expected to be the largest for the coming decade until the majority of villages in the western provinces will be connected to the grid in 2020
- new programs will stimulate the development of Rooftop and Building Integrated PV (BIPV) in the eastern provinces and the development of large PV power stations in desert areas. Grid connected PV is expected to take the lead about 10 years from now.

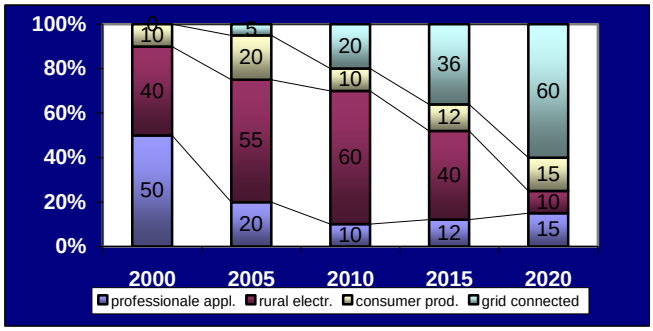

Figure 2: Relative share (real + projected) of PV market segments in China

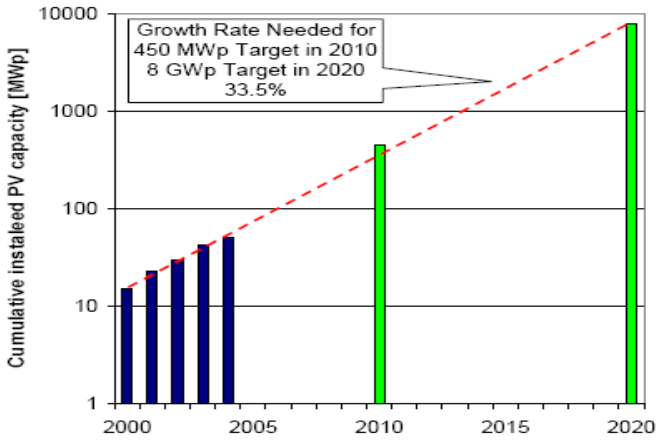

Figure 3: Possible development of cumulative installed capacity of PV in MWp in China derived from policy under discussion.

3 The China PV Industry

3.1 Status PV industry

Since the first PV cell was made in China about 50 years ago, industrial activities started for space, telecommunication, defense and petroleum related energy supply systems. In the mid-seventies China started to produce the typical small portable solar home boxes for rural areas. This market has (without any subsidy until 2000) developed successfully.

Before 2000 there were 7 PV manufacturers with a 2 to 3 MWp/yr production capacity, which was enough for the home market of mainly professional and rural applications.

Halfway 2004 (just before the PV boom) there were about 20 PV module manufacturers with about 20 MWp annual production (claiming a capacity of 100 MWp yearly).

Year	National sales	Totally installed	Produced cells	Produced modules	Cell capacity	Module capacity
1999	1	16	1	1	10	
2000	3	19	2,5	2,5	10	
2001	4,5	23	4,3	4,3		
2002	21,5	45	16,5	16,5		
2003	10	55	>10	10	80	80
2004	10	65	>50	?	100	>100
2005	5	70	145	284	150	857
2006					1450	>1000
2007						
2010	80	500	100			
2020	500	5000	2750			

Figure 4: Overview of national sales, production of cells and modules and production capacity of PV in China in MWp/year

3.2 Polysilicon production

By the end of 2005, the production capacity of polysilicon material in China was about 400 tons. In 2005 the amount delivered reached only 80 tons. There is a big gap between the production and market demand in China and most polysilicon material was imported abroad. In 2006 China adds 200 tons of production capacity. For 2007 1960 tons of capacity will be added, while for 2008 another 2000 tons added is estimated.

Polysilicon per year demand and production	2004	2005	2006 (proj.)	2008
Demand semiconductor industry (EG)（ton）	910	1092	1200	
Demand by solar PV industry (SG)（ton）	650	1729	3640	
Total demand（ton）	1560	2821	4840	
Delivery value of polysilicon（ton）	57.5	80	300	
Net imported（ton）	1500	2741	4540	
China production capacity estimate (ton)	?	400	600	4600

Figure 5: National demand and production of polysilicon for semiconductor and solar industry in China in tons per year

3.3 Silicon ingot manufacturing

The ingot manufacturing industry (for both semiconductor and solar industry) develops very fast recently by an annual growth of 70%. By the end of 2005, the production capacity of poly- and single-crystalline ingots has exceeded 5000 tons in China. Ningjin Jing Long Group has had a production capacity of about 2000 tons and became the biggest ingot manufacturer in the world.

At this moment (2005/6) the total capacity is 5792 tons (divided over 4800 tons of single-crystalline silicon and 992 tons of poly-crystalline silicon); the real output in 2005 has been 2436 tons (divided over divided over 2086 tons of single-crystalline silicon and 350 tons of poly-crystalline silicon).

3.4 PV cell manufacturing

Since 2004 PV industrial activities in China started to boom. The total production of solar cells during 2004 was exceeding 50MW, which was 4 times the value in 2003. In 2005 the total production was about 145 MW, of which Wuxi Suntech delivered 82 MW, then ranking the eighth biggest cell supplier in the world. However the manufacturing of solar cells would have developed even faster if the supply of silicon material would not have been a limiting factor.

It is estimated that the production capacity already in 2006 will reach 1450 MW, which is almost 10 times the value of 2005.

3.5 PV module manufacturing

In 2005, the module manufacturing capacity in China was 857 MW while the real production and delivery was 284 MW. This is about 15% of the total global production of PV.

Because of the shortage of solar cells in China, more than 50% of the solar cells were imported.

The module production capacity is easy to upscale due to the large share of hand labor, but therefore rather difficult to prognosticate, even for 2006. However the capacity is now already over 1000 MWp.

4 The WB/GEF China Renewable Energy Development Project (REDP)

4.1 Project Background

The REDP project was set up at the end of the 1990's. Observations in the Chinese SHS market around 2000 were:

- attention for PV and wind (larger wind and a bit less for small wind) especially in the academic sector and some 'new market' parties was growing rapidly
- sales of wind turbines was growing to over 100 MW/year
- sales of PV was growing above 1 MWp per year, increasing with 20% per year
- a unique Chinese portfolio of PV SHS products:
  - very small PV systems of 5-50 Wp per SHS
  - total-service-in-one-box concept
  - competition on price per service; not per Wp or kWh
  - quality and maintenance issues differ from SHS PV markets in other countries
- market development of SHS (and also other RE as solar hot water systems) was not financially stimulated yet
- improvement of quality of PV products was not supported
- no quality assurance (QA) system was used in China

For the prices of SHS in China around 2000 it was found:

- that PV modules >50Wp were sold at world market prices but with lower quality
- that PV-modules <50Wp (mainly laser cut cells) were much cheaper than elsewhere
- that PV solar home systems from China belong to the cheapest on the world market

Furthermore in 2000:

- China's economy and society was changing rapidly
- 20,000 villages and 20 million people did not have access to electricity.

In this situation a small dynamic PV distribution business was emerging, consisting of people from research institutions in Beijing, Shanghai and other eastern cities (knowledge), from provincial institutions (distribution) and sales people in the provinces (knowing the market). On one hand the national rural market was quickly expanding; but on the other hand PV suffered sometimes from lack of quality or deficient after-sales service due to the quick growth.

4.2 Project Intentions

The China REDP aim is to use state-of-the-art and cost-effective (wind and) PV technologies to supply electricity to remote areas in China in an environmentally sustainable way and to develop a persistent sustainable market.

The REDP will support 10 MWp of PV totally. It concerns about 300,000 PV systems mainly SHS for the north-western provinces and regions Tibet, Qinghai, Xinjiang, Gansu, Sichuan and Inner-Mongolia. See map of China (Figure 6).

The specific objective of the Technology Improvement (TI) component is to lower cost and to improve the quality of PV equipment in China. An important secondary (unofficial) aim of TI is to give the Chinese industry a better chance at competing with western industries in the renewable energy market in and outside China. Being more or less the only program with this goal from 1999 to 2004, Technology Improvement and Quality Assurance issues were of highest relevance.

Figure 6: Participating provinces (blue) in China

4.3 PV Market Impacts

Up to now the following successful (✓) or not-successful (–) market impacts of the REDP were prelimenarily assessed.

✓ *To provide basic energy services to remote areas*

- At the end of REDP far over 300,000 extra customers will have access to basic light;

- REDP was an important example to convince the Chinese government that PV is one of the prime technologies to bring electricity to remote areas, leading to new dedicated stimulation programs.

✓ *PV market acceleration*

- Establishment of a market-driven sales (& service) system for SHS: over 25 PV companies are now equipped to sell good quality PV systems in China;
- The costs of SHS was reduced from 80-100 Yuan before 1997 down to 50-60 Yuan per Wp. PV market has grown from 2MW in 1997 to 10 MW in 2004.

? *Sustainable development both for market as for technology development*

- o This impact is not clear on the longer term yet. On the one hand it is clear that PV companies are able to adopt improved technology, but on the other hand improved SHS's were not easily adopted by the customers;
- o Due to high prices of PV on the world market prices of SHS's did not go down in China from 2004 to 2006;
- o As the start of new stimulation programs was delayed, the national PV sales went down from 2003 to 2005.

Impacts on quality and Quality Assurance (QA)

✓ *Improvement of quality level without raising the price*

- For improvements for which the cost of the purchase was not higher, such as improved battery controllers, this impact was reached in an absolute way: Also several suppliers had to improve their quality as they were losing market share to a competitor with a higher quality or better features at the same price.
- The impact is also reached for improvements, where the higher price for the purchase in absolute sense can be justified by clear savings on short term. It was possible to convince the market e.g. for improved DC-lights. In other improvements with a higher absolute price, the market was not convinced (☹).

✓ *Quality level and QA and best Chinese market players*

- The extensive PV knowledge base already existing made it possible to assess the national state-of-the-art throughout the country rather quickly. The quality level chosen as the minimum level in the REDP was the quality level of eastern China and of PV institutes in Beijing and Shanghai. This forced local PV suppliers to work together with provincial institutes (with access to eastern China's technology) or with national institutes in eastern China.

✓ *Jumpstart through a List of Qualified Suppliers*

- It was possible to train 17 PV suppliers and to do simple and quick tests of qualified components by national testing centers to make a first list of Qualified Suppliers and qualified products. The short-cut on QA in principle worked very well. The lists were ready in a short period, and the project started with a limited but well-working QA-system within a year.
- In 2005 the List of Qualified Suppliers had over:
  - o 27 PV manufacturers
  - o 27 controller manufacturers
  - o 22 inverter manufacturers
  - o 10 DC saving light manufacturers
  - o And 37 storage battery manufacturers.

– Quality in Chinese PV market to reach international level

- o As said before the quality of PV products which are offered has generally improved substantially, this can not be said for what is finally sold. In general the Chinese market tends to buy a cheaper alternative, even though the quality is lower. Differentiation of the portfolio and competition at the low-end of the market is very high. Education of the consumer is needed to have the market really adopt the improved products. It can be concluded that for all improvements that lead to a higher price of purchase, the advantages have to be communicated much better with the customers.

Figure 7: Two of the most successfully adopted TI products by the market were the improved DC light and the controller

Industrial impacts in China

✓ *PV technology to reach international state-of-the-art*

- Several PV manufacturers have reached the international level for the production of cells and modules. Also on the system level the international state-of-the-art for quality will be reached. For SHS-systems below 50 Wp, the Chinese manufacturers are leading the international state-of-the-art, as well as for selected components as DC-lights and LED-lights.

✓ *Improved competition against western PV industry*

- We see that in 2004 Chinese PV modules can compete for the first time on a substantial level with western modules in the German market;
- Before 1997 there were 7 PV manufacturers with a 2-3 MWp year production; begin of 2004 this has grown to 20 manufacturers with about 20 MWp annual production (and 100 MWp production capacity);
- Since 2004 PV industry is booming especially for export. Of course besides the impact of the REDP there are many other success factors.

Fair competition in REDP projects and Chinese PV market

✓ *Modern competitive project selection*

- This impact was reached by establishing an effective management of the REDP and proposal selection mechanism and criteria. The competitive element is limited mainly to that between Chinese companies, as foreign companies turned out to be at the same project quality more expensive even when the work is carried out in China.

– Equal chance for foreign and national PV suppliers

- o There is no equal chance for foreign PV suppliers in the Chinese PV market of SHS's, except for some professional or selected subsidized niche-markets, where a higher quality level is demanded. This may be due to the fact that foreign PV suppliers did not develop product portfolio with a better price/per-formance and/or aiming at the low end of the market.

4.4 Use of Standards

In the China REDP it was chosen not to use internationally available quality standards, but to develop own standards:

- partly because international standardization process was very slow and quality standards for controllers, inverters, batteries were under development for many years, but were not available (IEC, GAP) and wer not able to deliver standards in time;
- partly because some areas important for the Chinese market were new for the international 'QA' community, such as dc-lights and LED-lights;
- also because the Chinese suppliers of PV modules could not reach the international quality level at that time.

The Project Management Office (PMO) established a quality standard, a first quality check and a quality verification system as a part of the overall project management system. The QA system functions up to now overall very well. This is due to the fact that all actors take the use of the standards very serious as the award of the subsidy is depending on the (verified!) use of qualified components.

Though all standards were developed for use in the REDP, they are now widely used in other projects in China and in the rest of the world. De facto the REDP standards are now widely recognized, accepted and used by actors in the whole PV market. The Chinese government has used the REDP standards as if they were national standards.

National standards (situation 2004)

Before 2003 there was no official Chinese standard for SHS's. On the subject the PMO organized expert's meetings with the relevant national standardization committee. It was decided to proceed as follows:

1. If there was a national standard existing (PV modules and batteries) the national standard will be the base for testing.
2. For components without a national standard (controllers, inverters, DC-saving-lights and SHS's on the system level) the REDP standards will be the base for testing.

A PV SHS or component can only be certified if a qualified test center will carry out the test. If a product fulfills the test requirements it will be certified according to the national standards, but automatically the PV product/supplier will also be listed on the List of Qualified Suppliers of REDP.

At the end of 2003 a draft 'National Technical Conditions and Test Methods for PV Solar Home Systems' was made based on the above policy, which was approved to be the formal national standard in 2004.

REDP has developed training programs for disseminating knowledge on this new standard in 2004 and 2005.

Module certification

Until 2004 most Chinese manufacturers sold PV modules which were tested against the Chinese standard GB-9535-1988. In 2004 and 2005 the TI component offered support to about 10 manufacturers to test their modules against the international standard IEC-61215. With this an important chapter (taking only about 5 years from the start of the REDP) in the race of the Chinese PV actors to catch up with the international state-of-the-art for PV modules was closed. Since mid-2004 daily reality has overtaken this important success: only one year later every self-respecting Chinese PV manufacturer is testing now against international standards.

4.5 SHS Factory Check within REDP

Within the REDP the PMO controls the quality of SHS's through an established Qualified Components Supplier List. The system integrators have to purchase components from the list in order to get the subsidy. The list is established by the PMO mainly based on test reports issued by a test lab accredited with IEC/ISO 17025. Starting from July 2006, in order to strengthen the manufacturing and management capability of the suppliers, the PMO requires module manufacturers and controller and inverter manufacturers to conduct a so-called Factory Check when they apply to be a 'Qualified Supplier'. Only the manufacturers who pass the Factory Check will get onto the list.

The findings of the Factory Check are as follows:

- generally, most of the manufacturers have obtained ISO 9001 certificate, thus, the quality control system is complete and the documentation is quite good;
- manufacturers paid great attention to the Factory Check. The manufacturers were informed of the importance of controlling the quality by improving management and manufacture process, and many manufacturers increased their investment in quality control facilities;
- the type of the products varies from one manufacture to another. It turned out to be is difficult to test all the products according to one standard. There is a need to define the new procedures for new types of products;
- in general the financial and management capabilities of the manufacturers have been largely improved since the REDP project just started;
- overall the REDP was successful in improving product quality although there are still quality issues to be solved.

System test and certification

In order to further improve the current SHS technology on the system level, increase system performance and efficiency as well as to help SHS integrators optimize their system design, the REDP initiated and developed a test on SHS's based on IEC 62124. The test focuses on the comparative testing of the performance of different brands and types of SHS's.

The results will be used to educate the customers on product quality as well as to help the SHS integrators to improve the system design, to reselect system components and to improve their system performance according to the test data.

Parallel the PMO supports the China General Certification Center to establish a national certification system on PV products with the aim to issue a SHS quality mark. The manufacturers will get the mark for those solar home or other PV systems if the systems pass the test as well as the Factory Check. In this way the achievements of the China REDP project can be made sustainable after 2006.

5 Conclusions and future outlook

The China REDP project substantially improved the quality of PV components produced in China and the professionalizing of Chinese PV industry. The REDP also has been crucial for the attention of the Chinese authorities and industry for PV in the beginning of this decade.

Other programs and investments have been 'triggered' by REDP; these programs might have had even more impact on industry and market development than REDP, such as:

- the Brightness-program (parallel to REDP)
- the Tibet Sunshine project (parallel to REDP)
- the PV Township program (from 2002, 20 MWp).

In the last two years several policy statements have been

made in line with:

- 2010: in total ~500 MWp PV solar to be installed
- 2020: PV capacity in China ~4 to 30 GWp installed
- the 'Market-Oriented Reform in China's Energy Sector' called for an improved legislation to stimulate RE
- Olympic Summer Games in Beijing in 2008 are baptized the 'Green Olympics'

The 'Renewable Energy Law' is approved February 2005 and active since 01/01/2006. The effect for PV is not clear yet.

The NDRC WB/GEF China REDP will be completed in 2006. Several new programs are on their way or under consideration:

- China - Renewable Energy Scale-up Program (CRESP)
- National Villages program (28.000 villages ad 5kWp)
  - until 2020: 140 MWp
- Green Rooftops Plan (100.000 rooftops ad 5kWp)
  - 4.000 in 2006-2010: 20 MWp
  - 96.000 in 2010-2020: 480 MWp
- Desert PV program (100 PV Power Plants ad 10 MWp)
  - 8 in 2006-2010: 80 MWp
  - 92 in 2010-2020: 920 MWp

If these programs and incentives are carried out, they will pave the way for a respectable Chinese home market of 1 to 5% of the global market. Chinese industry has shown since 2004 that they can do better than that: they are making up for a 10-50% share of the global PV production.

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