

SOLAR PHOTOVOLTAIC POWER THE GLOBAL SCENE AND A CLOSER LOOK AT CHINA

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Abstract

Solar Photovoltaic (PV) technology is rapidly expanding throughout the world. In 2004, 1,200 MWp of PV was manufactured, and annual growth for the past several years has averaged 30%. The manufacture and use of PV is dominated by Japan and Germany, but the industry is truly global. The International Energy Agency (IEA) supports a network and collaborative projects which support and track the global market. The UK has a small, domestic market and a modest national programme. But Britain plays an important role in building-integration and grid-interconnection of PV systems. Britain also leads the IEA programme on PV for Developing Countries, which is now also supported by the Renewable Energy and Energy Efficiency Partnership (REEEP), in order to extend its outreach and cover other renewable energy technologies. PV in China is developing rapidly, both for electrification of small towns and villages in remote areas, and in manufacturing PV cells & modules. The latter has been mostly for export, particularly to Europe, for the grid-connected market. There has been a rapid increase in manufacturing capacity, from 12MWp/y in 2000 to 104MWp/y in 2004. However, to-date, there is little experience in China with PV building-integration or grid-connection. Nevertheless, this could change rapidly with the implementation of the new Renewable Energy Law. The paper presents an overview of the world scene and reports on the latest developments in China.

Keywords

Photovoltaic, IEA, PVPS, China

1. Introduction

Photovoltaic (PV) technology converts sunlight directly into electricity. There have been remarkable developments in the science, technology and production processes over recent years. From an expensive power source used only in satellites or for small remote applications, PV has evolved into a product range which generates clean electricity at its point of use. PV is cost-competitive for applications remote from the electricity network (=off-grid), and remote can mean only a metre or so for small systems. For grid-feeding electricity, the capital cost of PV is currently more than for conventional fossil fuel generators. But with increased scale of production, technology improvements, and new materials under development, PV is expected to soon become

financially attractive for bulk electricity, especially for peak loads such as air-conditioning. The industry is expanding rapidly thanks to government incentives in several countries, which include loans, subsidies and generous feed-in tariffs which encourage investment by householders and companies. PV is now a global business, backed by major corporations and governments.

2. The Global PV Market

PV production is growing exponentially, as illustrated in figure 1 [Maycock, 2005]. This shows the increase in production to 2004, when almost 1.2 GWp was achieved. It can be seen that Japan is the largest producer, with 51% of world production. Japan has also been the world's largest user of PV, thanks to the government PV roof-top subsidy programme, and close government-industry co-operation. Europe is the second largest producer, and European companies own several of the major producers in the USA and rest-of-the-world (Australia and India). Germany is the fastest growing PV market because of an attractive feed-in tariff, and surpassed Japan for the first time in 2004.

Manufacture by producers is illustrated in figure 2, which shows Sharp of Japan to be the world's largest manufacturer, with 32% of production. Kyocera also of Japan is the 2nd largest producer. In third place, BP Solar has global production, principally in Australia, India, Spain and USA (but not UK).

China and Chinese manufacturers are just starting to show up in the statistics, and will certainly become significant in the near future.

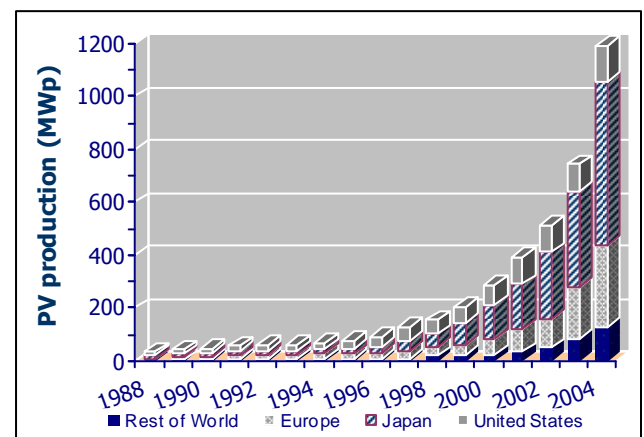


Figure 1: World PV cell/module production (1988-2004 MWp)

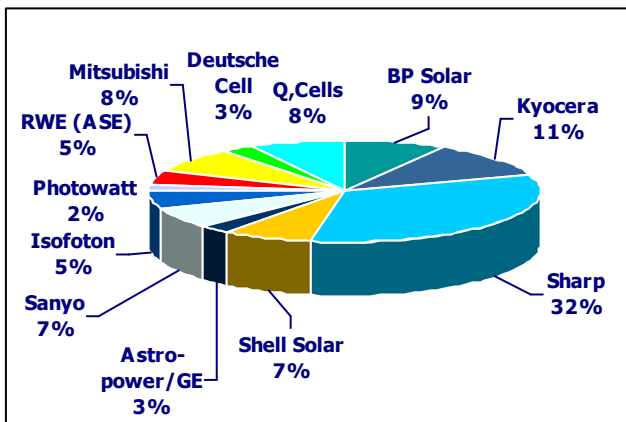


Figure 2: The leading PV manufacturers, 2004

3. The International Energy Agency Programme

The International Energy Agency (IEA) was founded in 1974 as an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) and carries out a comprehensive programme of energy co-operation among its 23 member countries, including the Photovoltaic Power Systems Programme (PVPS). Since 1993, participants have been conducting a variety of joint projects in the applications of PV.

The twenty participating countries are Australia, Austria, Canada, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States of America. The European Commission is also a member. Very recently, the European Photovoltaic Industry Association (EPIA) has joined IEA PVPS as a sponsor member. Non-IEA countries are also eligible to join, and there are on-going discussions with several, including China and Hong Kong.

3.1 Task 1 – Information Dissemination

Task 1 deals with the subject *Exchange and dissemination of information on photovoltaic power systems*. This represents a major crosscutting activity throughout the entire IEA PVPS programme. The Task is responsible for the regular 'PV Power' newsletter (produced under contract by IT Power), the website [<http://www.iea-pvps.org>], and the annual trends report on photovoltaic applications [IEA PVPS, 2005]. This is developed from National Survey Reports produced by each participating country. IT Power is contracted by the Department of Trade and Industry (DTI) to prepare the report and represent the UK on Task 1. The trends report has become a widely cited reference for the PV market development in the participating countries. More recently, non-member country data (including China) have also been included. This activity provides important results such as tracking the individual markets by their characteristic numbers and the trends in the different

applications. Besides the analysis of markets and applications, increasing effort is spent to understand and document the global industry structure and the relevant developments in this area, e.g. feedstock material. The report also provides important information on countries' efforts, programmes and frameworks.

The installed PV capacity in IEA PVPS countries is estimated to be 2.6 GWp by the end of 2004. The analysis confirms 2004 as the first year of a global shipment of PV modules greater than 1000 MWp. On a global scale, the PV installed capacity is estimated to be around 3.2 GWp which corresponds to an estimated energy production of greater than 2 TWh.

3.2 Task 2 – Operational Performance

Task 2 deals with the subject *Performance, reliability and analysis of photovoltaic systems*. The overall objective of Task 2 is to improve the operation, sizing, electrical and economical output of photovoltaic power systems and subsystems by collecting, analysing and disseminating information on their performance and reliability, providing a basis for their assessment, and developing practical recommendations.

Most recently, Task 2 has set up a survey on life-cycle costs of photovoltaic systems; the survey can be accessed through the website <http://www.iea-pvps-task2.org>.

3.3 Task 3 – Stand-alone systems

Task 3 dealt with the subject *Use of photovoltaic power systems in stand-alone and island applications* and was concluded in 2004. The Task focused on two main areas, quality assurance, and technical issues, in particular concerning load management, appliances and energy storage. The Programme is presently developing a new Task (11) with the provisional title *Sustainable PV-hybrid minigrids*. This Task will follow-up on the work of Task 3, focusing its efforts on the design and control of PV-hybrid minigrids. It further addresses interconnection and penetration issues of such systems. The Task should become operational in 2006.

3.4 Task 5 – Grid-connected systems

Task 5 dealt with the subject *Grid interconnection of building integrated and other dispersed photovoltaic systems* and was concluded in 2002. The overall objective was to develop and verify technical requirements as guidelines for grid interconnection with building-integrated and other dispersed power systems. The development of these include safety and reliable linkage to the electric grid at the lowest possible cost. Grid-connected systems largely dominate the present global PV market, making up for more than 80% of the installed capacity in IEA countries in 2004. A broad range of technical reports on these subjects are available at the IEA PVPS website.

3.5 Task 7 – Building-integrated systems

Task 7 dealt with the subject *Photovoltaic power systems in the built environment*, and was concluded in 2001. The objective was to enhance the architectural and technical quality and the economic viability of PV systems in buildings, and to assess and remove non-technical barriers for their introduction as an energy-significant option. The primary focus of the Task was on the integration of PV into architectural design (roofs and façades) and other structures. Hong Kong was represented by Hong Kong University as an observer in several of the activities. The Task put important emphasis on interaction with the world of architecture and building design. This work resulted in training material (CD-ROM) for architects and a recent book on design with solar power [Prasad, 2005].

3.6 Task 8 – Very large-scale systems

Task 8 deals with the subject of *Very large-scale photovoltaic power (VLS-PV) generation systems in remote areas*. The objective is to examine and evaluate the feasibility of VLS-PV in desert areas, which have a capacity ranging from over multi-megawatt to gigawatt, and develop practical project proposals for demonstrative research toward realisation of VLS-PV systems in the future.

Task 8 looks more into the future of PV as a means for large-scale power production. Indeed, it can easily be shown that arid regions in desert areas around the globe bear sufficient surfaces to cover substantial amounts of the world's electricity supply. The Gobi Desert in Mongolia has been used as a model for case studies [Kurokawa, 2003].

3.7 Task 9 – Developing Countries

Task 9 deals with the subject of *Photovoltaic Services for Developing Countries (PVSDC)*. The objective is to increase the rate of successful deployment of PV systems in developing countries. PVSDC is an outreach activity of IEA PVPS, both in looking beyond the IEA constituency countries as well as regarding the technologies covered. This is being promoted through enhanced co-operation and flow of information between the IEA PVPS Programme and the other international development stakeholders. PVSDC has drawn upon the experience of the participating countries aid and technical assistance programmes, as well as the work of agencies, such as the Global Environment Facility (GEF), World Bank and United National Development Programme (UNDP). The work is led by IT Power (contracted by DTI, and supported by the REEEP).

PVSDC's work with PV also takes account of other renewable energy technologies, such as micro-hydro and wind. The team advocates use of the most appropriate technology in particular circumstances and does not simply promote PV [McNelis & Arter, 2005].

A series of recommended practice guides on a number of

non-technical issues of rural electrification programmes (such as quality management, financing, capacity building and programme implementation) have been published and are accessible through the IEA PVPS website. In addition, objective and impartial information is published and disseminated through workshops and seminars held in all five continents, as illustrated in figure 3.

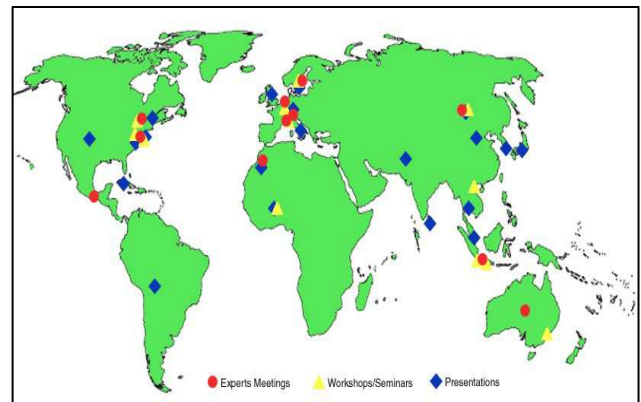


Figure 3: Dissemination activities around the world by IEA-PVSDC

More recently, PVSDC has increased its focus on PV as an energy source for basic services, such as lighting, drinking water and power for income-generating work, for the people without access to electricity. PVSDC has adopted the primary mission of increasing the sustainable use of PV in developing countries in support of meeting the targets of the Millennium Development Goals.

3.8 Task 10 – PV in cities

Task 10 is the most recent IEA PVPS activity and deals with the subject of *Urban scale photovoltaic applications*. The objective is to enhance the opportunities for wide-scale, solution-oriented application of PV in the urban environment as part of an integrated approach that maximises building energy efficiency and solar thermal and photovoltaics usage. Value analysis, policy incentives, analysis tools as well as system design and integration that have proven successful in the participating countries will be developed to the extent possible into a uniform international set of tools for the global market. The Task has taken the challenge to move this subject further and to provide a global network of experience to build upon.

Most recently, Task 10 has launched a new competition [Lisbon Ideas Challenge, 2005]. This is an international design competition aimed at fostering innovative ideas relevant to the development of urban structures integrating photovoltaic systems and technologies. The main novelty compared with earlier initiatives (e.g. PVPS Task 7 Design Competition) is that the ideas should not

only have a technological potential but also business potential; the latter should be demonstrated through a business plan.

4. PV in the UK

Despite the usual jokes; “the sun never shines in Britain”, the UK has had a small but effective involvement in PV development and application for the past 25 years. University researchers, leading international consultants and major industry (BP Solar) together formed the British Photovoltaic Association (PV-UK) in 1991. The Association developed a Strategy [PV-UK, 1999] and lobbied government to provide support for research and a demonstration/market enablement programme. The UK’s Major Demonstration Programme was launched in 2002, with a budget of €30 million, later increased to €3 million, available as capital grants, typically 50%. The effect of this has been to stimulate the market, as illustrated in figure 4. This shows cumulative installed capacity reached 8.2 MWp in 2004. A total of 2.3 MWp was installed in 2004, an increase of 28% compared with 2003 [IT Power, 2005].

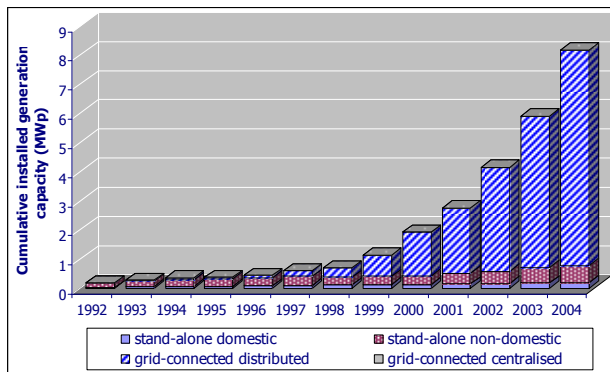


Figure 4: Cumulative installed PV capacity in the UK 1992-2004

There is one indigenous PV manufacturer, ICP Global Technologies (previously Intersolar, previously Chronar UK) which produces amorphous silicon plate (1.5 MWp in 2004), while Sharp opened its European PV module plant in the UK in 2004. This is a capacity of 20 MWp/y and will increase to 40 MWp/y. Romag, a specialist glass company produces glass/glass modules to order, with a lamination facility with a capacity of 6 MWp/y. The British company, Chrystalox, produces multi-crystalline silicon for wafer and cell manufacture, exporting sufficient material to produce 185 MWp in 2004.

The UK's largest PV System of 391 kWp is currently nearing completion on the Co-operative Insurance Society (CIS) Tower in Manchester, as illustrated in figure 5. This is a 'listed building', as it was the UK's first 'skyscraper', built more than 40 years ago, and now in need of façade refurbishment. The project is undertaken by Solar Century using Sharp PV modules.

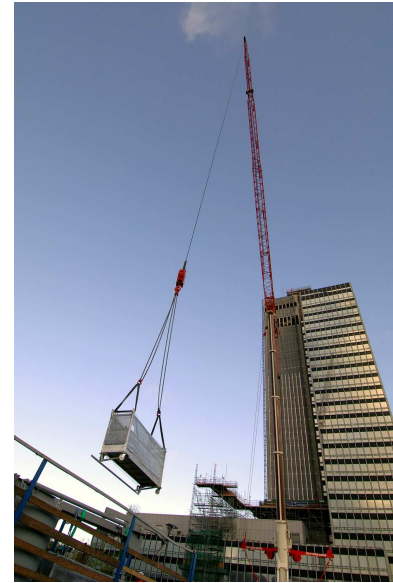


Figure 5: PV being installed on the CIS Tower in Manchester, using the UK's largest crane (July 2005).

The current government programme will end in March 2006. A new low-carbon buildings programme is currently under development for 2006, and it is expected to include PV.

5. PV in China

China has a uniquely diverse economy compared with other (so called) developing countries. It has remained the fastest growing economy in the world for the last 15 years, with an average annual GDP growth rate of 8%. More than 80% of China's total population still live in rural areas, supplying 130 million migrant workers for the labour market, so that its labour costs remain among the lowest in the world. There are about 28 million people in around 7 million households in 23,000 villages without access to electricity. China not only presents significant potential market for PV, but also offers a cost-competitive opportunity for PV manufacturing.

Statistics on PV installed in China are not considered very reliable. One estimate is that 75 MWp was achieved cumulatively in 2004, as illustrated in figure 6 (Zhu, 2005a). The PVPS Trends Report quotes 65-75 MWp. China is becoming increasingly open with market data and experiences, and welcoming co-operation with the world PV community. For example, the Chinese technical standard for PV modules was changed to be in line with the International Standard set by the International Electrotechnical Commission (IEC), and China hosted the last IEC PV meeting in Beijing in May 2005.

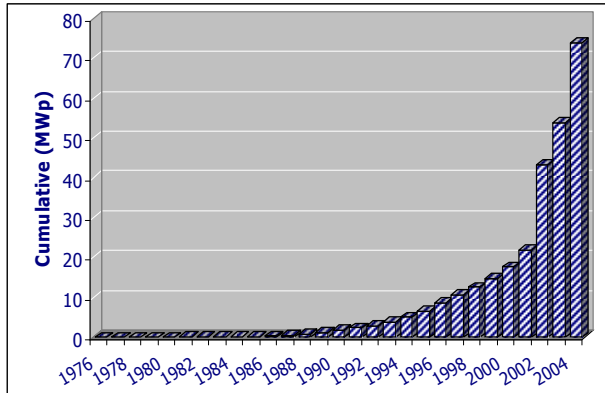


Figure 6: Installed PV capacity in China

5.1 Rural Electrification

The Chinese PV market is dominated by rural electrification projects. The biggest market driver has been the National Rural Electrification Programme, the so-called Song Dian Dao Xiang; 'Sending electricity to townships' [Zhu, 2003]. So far, this is the largest and most prompt village power Programme in the world, as ¥2 billion (US\$242 million) has been provided by the central government for a total investment of ¥4.7 billion (US\$560 million) for the electrification of nearly 1000 rural townships in north-western provinces over two years.

Rural electrification now accounts for more than 60% of the total PV market in China. A more ambitious rural electrification programme, the so called Song Dian Dao Cun; 'Sending electricity to villages' being prepared by the Chinese Government, with the aim of installing 100–150 MWp of PV village power systems in the period 2005–2010. The total investment could amount to US\$5 billion over 10 years [Wallace, 2005].

5.2 PV manufacture

PV manufacture in China began in the early 1970s but technology and output was a long way behind other countries until recent years. By 2000, there were seven PV manufacturers with a total production capacity of 12 MWp/y for cells and modules. All of the production lines were financed through government R&D schemes or international aid programmes for technical demonstration, and all were small in scale. The largest of the lines had a capacity of only 2 MWp/y.

Wuxi Suntech Power is the largest PV manufacturer in China. By 2004, the module production capacity had reached 50 MW. After a recent investment of US\$75 million, by the end of 2005, the new production line will be in operation bringing the total capacity to 100 MWp/y. Suntec is becoming a major world supplier. Kyocera is the first Japanese company to produce PV modules in China. The company recently announced the 12 MWp/y module production line in Tianjing City. [Zhu 2004, 2005a).

5.3 Renewable Energy Law

After 18 months in preparation, the Chinese Renewable Energy Law was formally endorsed by the Standing Committee of the National People's Congress on 28th February 2005. Renewable energy development in China has been at its highest level on the political agenda ever. This shows the government's commitment to renewable energy development and its desire to tackle environmental problems and the emerging concerns of energy supply [Zhu, 2005].

The law includes provision for various types of grid-connected renewable energy power generation and stipulates that grid enterprises must purchase the grid-connected electricity generated from renewable sources and provide grid-connection services. The price of renewable electricity power generation will be determined by the price authorities and the excess shared in the power selling price within the coverage of the grid. The Law will be effective in January 2006. Wind and hydro systems are already being developed in anticipation of attractive payments to be received as a result of the law.

Along with passing of the law, the Chinese government also set up a target of renewable energy, which will increase to 10% of the country's gross energy consumption by 2020, from the current 1%. Seeing this as a future key market driver, the Chinese, and international businesses are excited, and expect a tremendous growth in the next 15 years.

5.4 Building-integrated, grid-connected systems

Shanghai, Beijing and Shenzhen, are the beacons of prosperity in China. These richest cities are facing energy supply and environmental problems. Housing construction in medium and large cities is growing at 50% annually. China will need 1 billion square meters of new housing for the next decade. Will China join the trend of supporting/subsidising building-integrated grid-connected PV through the Renewable Energy Law? It is difficult to predict when China will issue a clear policy on building-integrated or large-scale PV systems.

The National Development and Reform Commission (NDRC) is overseeing the implementation of the Renewable Energy Law, and while it has set targets of 20 GW of wind and 20 GW of biomass by 2020, there are no targets for PV electricity generation. It may be that the hard-nosed Chinese economists will decide PV is too expensive. The world PV community is observing closely [Hirshman, 2005]. The government, through the Ministry of Science and Technology, has started to spend money on demonstrations and R&D. A 1MWp installation was recently completed in Shenzhen, as illustrated in figure 7. PV was supplied by BP Solar. The new Capital Museum in Beijing is scheduled to be opened in October 2005. This includes 300 kWp of PV supplied by UniSolar on the roof. The Building, as seen from Chang'an Jie is shown in figure 8. Unfortunately, the rooftop PV will not be visible.



Figure 7: PV installation on main hall of International Garden Expo in Shenzhen, part of 1MWp system, Guangdong Province



Figure 8: Beijing Capital Museum under construction (July 2005)

6. Conclusions

PV manufacture and applications are expanding exponentially, driven by market enablement programmes as a result of government policy in several countries, varying from very large (e.g. Germany ~600 MWp/y) to very small (e.g. UK ~2 MWp/y). China has a clear policy for PV for electrification of remote towns and villages, which is part of the largest such rural electrification programme in the world. Manufacture of PV in China is attracting serious investment, and there are claims that China will become the PV supplier to the rest of the world (like it already supplies toys, garments etc.). China is just starting to demonstrate and experiment with building-integrated grid-connected PV. There is no programme, as in Germany, UK and elsewhere, but the new Renewable Energy Law, which will lead to mechanisms to pay a price realistic for the cost of electricity generated from renewables (like hydro, wind and biomass), could also be

applied to PV, if the government is prepared to pay the price. This would be exciting news for the PV industry in China, and the rest of the world. China may be on course to become the world's largest PV producer. China could also become the only country in the world to have both rural electrification and building-integrated PV markets. There is also scope for VLS-PV in the desert areas. Participation by China in the IEA PVPS Programme would be very welcome and would be beneficial to all the stakeholders in the global PV community.

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