SPV 2009

Solar Photovoltaic Report

Edition 6 – 2009

ABS Energy Research

The Solar Photovoltaics Report
Ed 6 2009

Introduction

2008 was a record year for solar PV sales, with 5.7 GW of new capacity added. Spain shot into top place, with 2.7 GW added, the largest volume of annual sales achieved by any country ever, followed by Germany with 1.5 GW. Between them they accounted for three quarters of world sales. However, Spain's pre-eminence was short-lived and in the wake of the financial crisis the Spanish government announced a cap on the feed-in subsidy for solar PV installations at 500 MW in 2009. This will not only put a brake on Spanish sales but will reduce the global solar PV total in 2009, we believe by at least 50%. The Spanish renewable associations are looking ahead at least two years before recovery starts in Spain.

The slow down in solar PV sales has had some good outcomes however. The shortage of silicon, which has been restraining development, is no longer a major issue and by the time recovery starts new supply should be in place. Secondly, prices of solar modules are coming down. Thirdly, small companies in the supply chain are merging and being taken ove, consolidating the industry.

The report, monitors the progress of two new players in the international market, China and Korea. Chinese solar PV companies have developed very fast and a number conducted IPOs in China and other countries in 2007 and 2008. A mushrooming production capacity for solar cells and modules has been accompanied by growing production and re-cycling of silicon. This is affected by the global slow-down but the Chinese industry is already well placed for the future. Domestic demand in China has not kept pace and it is an export oriented industry to date.

With the cut-back in Spain, Germany, followed by Japan and the USA still remains the global leader, but new countries are entering the market and the industry is spreading beyond its historical areas.

Outline of report

- The report provides data up to the end of 2008 with commentary and available information for 2009
- Spain was a bright shooting star in 2008 but with the financial crisis has fallen to earth in 2009
- Germany is consolidating its position in 2009 as the largest solar PV market, followed by Japan and the USA
- The dramatic emergence of China as a world player, with ambitious expansion plans for Solar PV
- The surge of IPOs in the solar PV industry in 2006-2007/08 has come to a halt, and consolidations are taking place in the industry
- The silicon shortage is evaluated, the future outlook discussed
- New feedstock technologies and sources are emerging to combat the global silicon shortage

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Table of Contents

2. Development of Solar Photovoltaics

Solar energy is usually divided into two categories, although they can be employed together in solar installations.

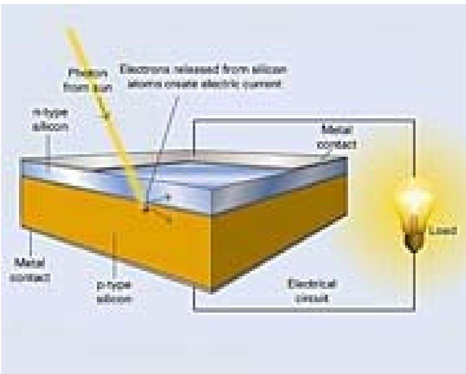
- Solar thermal energy is generated from the sun's **heat** and employs this directly to heat water or buildings, or to produce steam to power electricity generators.
- Solar photovoltaic electricity is generated from the sun's **light**, employing photovoltaic modules with cells, which convert sunlight into electricity using semiconductor devices.

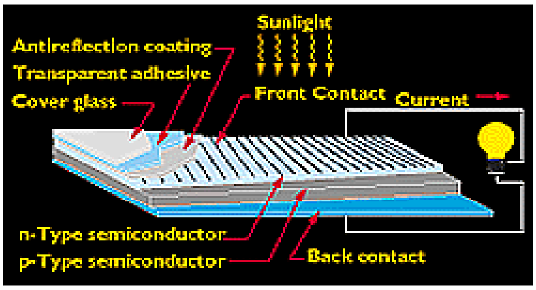
This report is concerned with the second of these technologies, Solar Photovoltaics. Solar Thermal Power is the subject of another report published by ABS, Solar Thermal Power Ed.2 2009.

Solar photovoltaics

Solar photovoltaics or solar PV are solid-state semiconductor devices that convert light directly into electricity. Solar PV's are mostly made of silicon with traces of other elements and are closely related to transistors, LEDs and other electronic devices. The electricity is direct current but can be converted to alternating current or stored for later use.

Figure 2-1 How Solar Works





Source: BP

Bell Lab. researchers discovered the working PV cell in 1954 when examining the sensitivity of a properly prepared silicon wafer to sunlight. From the late 1950s, PVs were used to power US space satellites, which generated commercial applications for PV technology. The simplest PV systems power many of the small calculators and watches in everyday use. More complex systems provide electricity in off-grid applications and generate electricity for power grids.

Advanced technology is required to manufacture PV cells and modules, but the cells themselves are simple to use. PV modules which are multiple cells are usually low-voltage DC devices with no moving or wearing parts, although arrays of PV modules can be wired for higher voltages. Once installed, a PV array does not require much maintenance except for an occasional cleaning, and even that is not imperative. Most PV systems contain storage batteries, which require some water and maintenance similar to that required by the battery in a car.

A solar cell consists of layers of semiconductor materials with different electronic properties. In a typical solar crystalline silicon cell, most of the material is silicon. The silicon is doped with a small quantity of boron to give it a positive or p-type character. A thin layer on the front of the cell is doped with phosphorous to give it a negative or n-type character. The interface between these two layers contains an electric field and is called a junction. Light consists of particles called photons and when the light hits the solar cell, some of the photons are absorbed in the region of the junction, freeing electrons in the silicon crystal. If the photons have enough energy, the electrons are able to overcome the electric field at the junction and are free to move through the silicon and into an external circuit. As they flow through the external circuit they give up their energy as useful work (turning motors, lighting lamps, etc.) and return to the solar cell. The photovoltaic process is entirely solid-state and self-contained; there are no moving parts and no materials are consumed or emitted.

Solar cell development

There are three generations of technology in the solar PV market. The first generation (Gen 1.0) has been in use for more than 50 years and uses silicon as its basic material. Solar PV based on silicon is a mature market with the best conversion efficiencies and lifetimes, it is also the most expensive. It is costly and challenging to bring a solar wafer plant on-line and production very much resembles that of the large scale facilities of the semiconductor industry, producing thick crystalline silicon cells and modules, which include single crystal and poly crystal, cast silicon and ribbon silicon.

- **Mono-crystalline** modules have individual cells and are uniformly black or dark grey in colour. Light conversion efficiency is 13-15%
- **Poly-crystalline** modules have a crazed pattern with blue cells. Light conversion efficiency is 12-14%

About 20 years ago a second generation PV technology (Gen2.0) was introduced, commonly referred to as thin-film (TFPV). The cells are made by covering a carrier with a thin layer of a combination of materials, such as copper, indium, selenium or cadmium telluride. In general, Gen 2.0 technology is cheaper to make than Gen 1.0, because it is lightweight and flexible. Gen 2.0 conversion efficiencies are lower than for plain silicon, which has traditionally limited its usage, but efficiencies are approaching 10%, close to Gen 1.0, with better potential for lower costs. Amorphous silicon also falls into the Gen 2.0 category, using only a small amount of silicon compared to Gen 1.0.

Thin-film cells and modules made from a number of layers of photosensitive materials, of which there are three types, all with active layers in the thickness range of 1-10 microns, and can be manufactured in large volume at low cost.

- **A-Si** - amorphous silicon cell. Amorphous silicon (a-Si) was the first thin-film material to yield a commercial product. Initially, a-Si was mostly used in consumer items such as calculators. Amorphous silicon is growing its markets as its efficiency increases, and new products are developed, such as modules that double as roof tiles, or semi-transparent modules for building-integrated uses
- **CIS** – copper indium diselenide / cadmium sulphide heterojunction cell. Copper indium diselenide (CIS & CIGS) has been introduced to the market, after two decades of R&D, with prototype modules reaching efficiencies over 11%
- **CdTe** – cadmium telluride / cadmium sulphide heterojunction cell. Cadmium telluride (CdTe) is an excellent semiconductor for solar cells because its bandgap of 1.4 electron-volts is matched almost perfectly to the solar spectrum. The device structure also includes a very thin layer of cadmium sulphide that allows most sunlight to pass through to the CdTe layer. CdTe is capable of high efficiency and can be used in low-cost modules

Third generation PV (Gen 3.0) is very much in its infancy and leaves the traditional semiconductor space altogether. Prototypes that produce electricity at relatively low conversion efficiencies are available, and solar cells printed on plastic or glass using organic materials have been cultivated by some start-ups.

Gen 3.0 technologies include: organic dye sensitised solar materials, silicon nanorods for solar cells, silicon ink solar technology, electron carrier multiplication in nanocrystals, the use of nanoscale structures for solar absorption and collection, quantum dot solar technology, and carbon nanotube technology in solar energy

Concentrator cells and modules have a lens which is used to gather and converge sunlight onto the cell or module surface the power levels can be of such dimension they are discussed in terms of ‘number of suns’.

Single crystal cells have an efficiency of up to 25%; poly crystal cells 20% and thin film about 16%. 84% of past and present module production has included thick silicon technology. The future plans of many companies include a commitment to thin film technologies but progress is varied and single and poly-crystalline production is scheduled to expand over the next few years. A small number of solar PV companies have committed themselves exclusively to thin film technology, notably Shell Solar, which has divested its poly silicon interests and is focusing solely on thin film.

15. Forecasting a new technology

Experience curves and progress ratios (PR)

Relative to the mainstream energy technologies which have been established for many years and whose development can be predicted on the basis of past performance, the behaviour of most renewables is less well known. Wind power is now well documented, but experience is now showing that there are costs and problems in its operation which were not properly anticipated. More is becoming known all the time about solar photovoltaics, but one unknown remaining is the extent of cost reductions for the established technologies such as polysilicon and the cost of the new technologies. There is not yet enough knowledge to make predictions as safely as about oil, coal, gas, nuclear and large-scale hydropower energy. However we are not totally impotent. Industrial theory has developed statistical techniques to assess the development of new technologies and processes on the basis of empirical evidence to date and comparison with other industries and technologies.

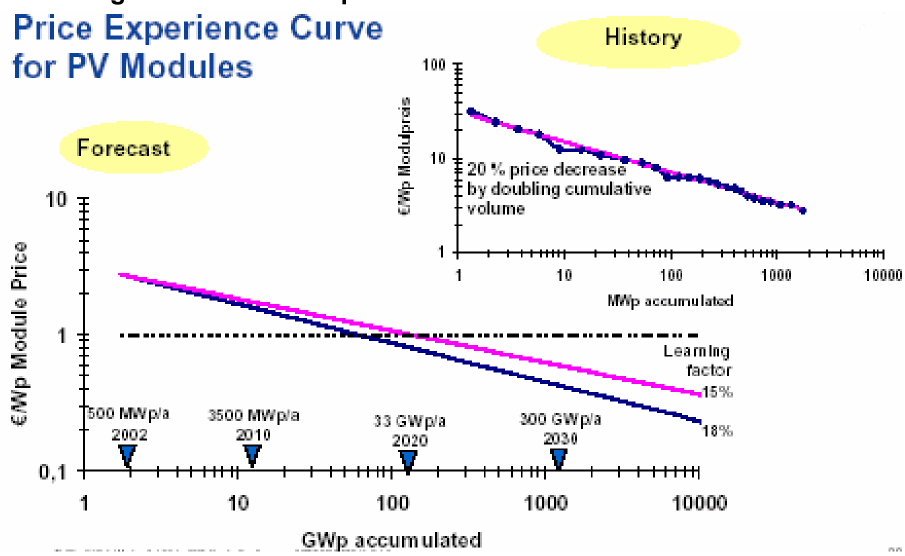
Progress in manufacturing process and technology is often described with a 'learning' or 'experience' curve. These curves are conventionally plotted using logarithmic axes, to show unit cost versus cumulative production. This usually produces a straight line over a large range of actual production volumes and the slope or gradient of the line is called the 'progress ratio (PR)'. Most manufactured goods or technologies yield progress ratios between 70% and 90% and 80% is the general average.

A progress ratio of 80% means that with each doubling of volume produced, the price falls by 20%, down to 80% of the cost of the first batch. The progress ratio can be calculated in terms of cost per unit manufactured, e.g. per wind turbine, cost of installation, cost of electricity produced, or any other component of cost.

There is currently a lot of activity in the world of energy analysts and planners to refine this theory, as more empirical evidence becomes available and the new energy technologies advance.

During the development of a new manufacturing technology, the PR usually starts at a low value, yielding large cost reductions and rises as the product is developed and the rate of cost reduction decreases.

Figure 15-1: Price experience curve for PV modules



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