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Sustainable Investment

Solar Energy 2005

Silicon supply bottleneck at odds with booming demand

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Executive Summary

Photovoltaics

Last year global **photovoltaic (PV) cell production** rocketed more than 60%, from 750 MW in 2003 to well over 1,200 MW. The fifteen biggest PV cell manufacturers were responsible for roughly 90% of the total production volume.

Fears of a world wide silicon shortage came true, and this has already curbed the rate of growth in 2004. New agreements have been reached between the photovoltaics industry and silicon manufacturers to increase production capacities for solar-grade silicon, and these capacities should come on stream during the course of 2008. But even then the supply bottleneck will not be fully removed. In future we are bound to see ingot and wafer producers enter into more joint ventures with silicon manufacturers in an attempt to ensure their own silicon requirements are met.

This persistent shortage will force companies to develop new processes that consume fewer materials. These efficiency improvements will have a positive impact on costs. Except for a number of niche applications, photovoltaics will continue to rely on government subsidies, however. Apart from the three biggest markets of Germany, Japan and the US, other countries now have substantial programmes in place to promote solar energy, including Spain, China, India, Italy, Portugal, South Korea and Thailand.

In 2004 the amount of **PV capacity installed worldwide** came to 840 MW, which corresponds to around two-thirds of solar cell production. This is equivalent to 40% growth on last year. Germany's installed capacity (360 MW) overtook Japan's (270 MW) for the first time, mainly thanks to the higher feed-in tariffs.

The uncertainty in the German market about possible cuts in these generous tariffs has been allayed following the recent elections. No changes are expected until 2007 at the earliest, when the Renewable Energy Act (EEG) comes up for regular renewal.

In the coming years the markets that currently dominate will become less important in relative terms. According to our estimates, Germany's share of the global market, for example, will drop from its current level of 43% to just 6% in 2020. Within Europe, Spain is becoming increasingly important, while in Asia the big markets include not only China and India, but now also Thailand and South Korea. The fact that more than two billion people in the world still have no access to mains electricity clearly demonstrates the enormous potential of photovoltaics in future. In the longer term, off-grid applications are more compatible with the sustainable character of photovoltaics than heavily subsidised megawatt installations built on greenfield sites industrialised countries. There is thus a pressing need to push ahead more with supplying electricity in Africa, Asia and elsewhere, before photovoltaics comes up against its limits in the western world.

Another challenge for photovoltaics is the avoidance of hazardous substances such as lead and cadmium in the manufacture of PV installations, and the establishment of take-back systems for equipment that has reached the end of its working life. As a form of renewable energy that still has a spotless "green im-

age", and given its explosive rate of growth, the solar industry would do well to be proactive in anticipating certain legislative trends and collaborating as an industry in effective solutions at an early stage.

For years now, our forecasts for the **future growth** of the PV market have been rather conservative compared with other market estimates. Given the shortage of silicon, however, we think our more cautious stance is justified for the coming two to three years. For the longer term, however, we have increased our previous forecasts and now estimate that newly installed global capacity will climb to around 3,000 MW by 2010. This is equivalent to an average annual growth rate of 24% for the period 2004 to 2010, and 18% for the following decade (2011-2020).

Solar collectors

Soaring oil and gas prices mean that more public attention is now being given to solar thermal power. Hardly any other technology saves as much fossil fuel and carbon dioxide as installations that generate solar thermal power. In many countries there has been no political and legislative support for this form of energy to date. Even so, solar thermal power already supplies more than 18 times more energy than photovoltaics at present.

Worldwide more that 30% more **solar collectors were installed** (with a total capacity of 11,700 MW_{th}) in 2004 than in 2003, with roughly 75% of them in China. The dominant feature of the Chinese market is that energy is expensive and in short supply. Given this backdrop, solar-powered hot water supply for households (90% of the market) is a competitive technology purely on cost grounds.

Europe's solar thermal power market has developed well, growing by 13% in 2004. The European market is still dominated by three countries, Germany, Greece and Austria, which have a combined market share of 75%. The biggest up-and-coming markets are France and Spain. Germany, Europe's biggest market, only grew 4%. Solar thermal power seems to be a second choice for owners of detached homes in particular, because of the attractive feed-in subsidies for photovoltaics. But the situation could change rapidly in view of persistently high oil and gas prices and new legislation to encourage subsidies (at EU level as well). It should be possible for the existing expansionary trend to continue up to 2010, although growth rates will be significantly higher if additional subsidy programmes are introduced.

For the current year 2005 we predict that newly installed collector capacity worldwide will reach around 15.5 GW_{th} , which is 32% more than last year. This growth will come mainly from the boom in China, but also from other non-European countries. The global growth rate is likely to remain between 25% and 30% up to 2010. We therefore predict a market volume (newly installed capacity) of 55 GW_{th} in 2010, with roughly 250 GW_{th} on stream worldwide. As the market gradually matures, we expect average growth will then ease back in the following decade (2011- 2020) to around 20% p.a. The global market for newly installed solar collectors would therefore reach a volume of approximately 390 GW_{th} in 2020.

The technology for solar-assisted cooling will be an important growth driver in future, especially in countries with a lot of sunshine and rising demands for personal comfort. Here combined heating and cooling systems can help to alleviate the critical peak loads that can occur at the height of summer.

Solar thermal power stations

In the last two to three years plans have multiplied for new power generation projects in response to technological advances and also more attractive political and economic conditions, including climate protection agreements, soaring oil and gas prices, subsidy programmes for renewable energies and generous fixed rate payments for solar energy supplied to the mains grid. In Spain and the US especially, the conditions for encouraging solar thermal power stations have improved significantly. However, such large-scale projects involve protracted procedures to get planning permission and secure the funding.

There have been very few changes to the list of projects we published in last year's report. So far none of the planned power stations have come on stream. At the moment the total power station capacity actually in service worldwide is 350 MW. This capacity originates exclusively from the first boom phase at the start of the nineties. Even so, concrete projects are now being constructed or are in an advanced planning stage. Future development relies heavily on the success and experiences of these pilot projects. Based on the projects planned, we think that power stations with a total capacity of 1,500 MW could be realised by the end of 2008.

Introduction

Focus on total solar energy use

For the third consecutive year, Sarasin's solar energy report studies the three solar applications **photovoltaics,** s**olar thermal power** and **large-scale solar thermal power stations**. Our decision to concentrate not only on solar energy but also on solar thermal power now seems to be paying off, as public interest has risen sharply. The newly agreed conversion factor of 0.7 used to translate the surface area of the collector (in m^2) into energy output (megawatt thermal or MW_{th}), makes it easier to compare solar thermal power with other renewable energies and gives a better picture of its true importance.

Short-term forecast for the most important markets

Our regional review of the three biggest PV markets – Germany, Japan and the US – and their performance revealed an upbeat picture. In particular, all eyes are on developments in the German market, whose progress could well set the course for the immediate future of the global photovoltaics industry.

Solar industry facing supply bottleneck

The shortage of solar-grade silicon referred to in last year's report is becoming more and more acute. The big manufacturers of solar-grade silicon are working flat out to expand their production capacities. This year's report provides the latest information on the future expansion of global capacities. The PV industry is also trying to make its production processes more efficient in order to produce more power (in megawatts) from less silicon. We also describe the latest technology trends.

Focus on off-grid systems in developing countries

Despite the attraction of fixed-rate payments for solar energy supplied to the mains grid, it is important to look beyond the principal markets for grid-connected systems in Germany, Europe and Japan. A far more important dimension – at least as far as sustainability is concerned – is the supply of electricity to rural areas in the Third World, and this market segment is now gradually starting to develop. Considering the problems of global climate change, the use of photovoltaics in developing countries has high priority. This is not only true from the environmental or humanitarian perspective, but also from an economic viewpoint, since with these applications photovoltaics often compete with diesel generators and are increasingly becoming a competitive alternative in financial terms as well.

Just how sustainable are PV systems?

For a long time the energy payback period, i.e. the time span for a system to produce more electricity than was required for its manufacture, was considered to be relatively unfavourable for PV systems especially. An environmental audit using new data material based on the latest technologies shows that the energy payback period is now only about two years, depending on the type of PV cell used.

Effects of new European environmental legislation

At the moment the photovoltaics industry is not affected (or only marginally affected) by the new EU directives on waste of electric and electronic equipment (WEEE) and the restriction of the use of certain hazardous substances (RoHS), such as lead in solder or cadmium. The solar industry would do well to take a proactive approach in meeting these challenges.

Long-term forecast up to 2020

As usual, the PV chapter of our report finishes with a long-term forecast for the future of the PV market. This time our forecast is based on the new PV capacity installed each year. The two targets used in our forecast are 2010 and 2020.

Solar collector chapter: country info and latest applications

Our chapter on solar collectors provides a description of the most important markets such as China, Germany, Greece and Austria. As in our 2003 report, there is a separate chapter on the most important European players in the solar thermal power industry. We also provide a short-term forecast (up to 2007) for the European solar thermal energy market. Our long-term forecast shows global trends in solar thermal power up to 2020.

Solar-assisted cooling: an important new market

The use of solar power for cooling and refrigeration is attracting more and more interest. Keeping rooms cool in summer creates enormous peak loads in many hotter regions of the world. Here the sun can provide a desperately needed alternative.

Solar thermal power plants: IPO of Solar Millennium

Solar thermal power plants are now becoming an attractive proposition for financial markets as well. In August 2005 Germany's big project development and construction company *Solar Millennium* floated on the stock market. It is already building its first new power plants in Spain. This chapter provides an update on all the global projects currently under way.

Photovoltaics (PV)

Silicon supply

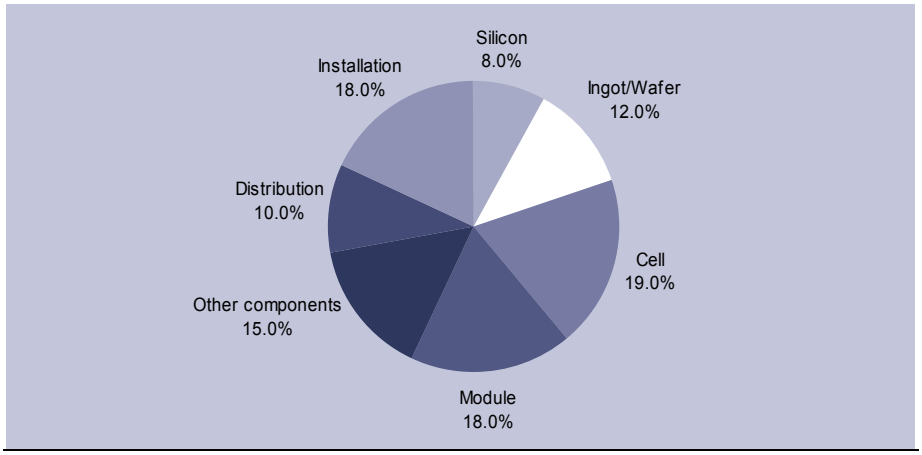
Bottleneck in supply of solar-grade silicon is holding back industry growth

The shortage of solar-grade silicon we predicted in our last report has now become reality and will prevent the solar industry from growing at its full potential in the coming years. With the current technology based on wafers cut from silicon ingots, the PV industry requires approximately thirteen tonnes of silicon per megawatt of solar cell capacity. In 2004 the industry needed just over 14,300 tonnes of solar-grade silicon to produce roughly 1100 MW of silicon-based PV cells (around 92% of total cell production). Rocketing demand for solar-grade silicon, combined with limited opportunities for rapid expansion of capacities, has caused silicon prices to jump from around USD 25 per kilo in 2003 to roughly USD 50 at present. Prices as high as USD 60-70 per kilo are being paid on the spot market. Prices for semiconductor silicon have risen as well and are roughly USD 10 higher than the price of solar-grade silicon on average.

Silicon component more expensive

With solar power, the creation of added value starts with silicon and moves in a clockwise direction in Fig. 1 below. The cost components shown apply for an average grid-connected PV system mounted on a roof. Compared with last year, prices have risen for silicon, ingots/wafers, cells and modules, which now make up more than 55% of total costs. By contrast, the cost of components that are not dependent on silicon has not risen. Prices for power inverters, for example, have dropped around 5% and we expect the prices for other accessories, distribution and installation to continue falling in the coming years.

Fig. 1: Cost components (in %) of a PV system (excl. tax)



Source: Sarasin, 2005

Silicon accounts for about 8% of the total cost of a PV system. The increase of around 100% in the price of this key raw material has pushed up the end price of a PV system by roughly 6-7%. This has put increasing pressure on the margins of producers involved in the silicon-based value chain.

The big silicon producers were slow to respond to the solar boom to begin with. Since the end of 2004, however, they have expanded their capacities, particularly for solar-grade silicon. Depending on the scale of the existing infrastructure, it can take up to 2-3 years to construct an additional production facility. The sili-

con supply bottleneck is therefore unlikely to improve much before 2008 at the earliest.

Silicon and wafer manufacturers are exploiting the current shortage to force cell producers into making long-term supply agreements. These include purchase commitments over several years and in some cases even involvement in the pre-financing of new silicon production plants. *SolarWorld*, for example, has safeguarded its raw material supply by concluding 10-year contracts with the silicon producers *Hemlock* and *Wacker*.

Expansion plans of silicon producers

Only seven large companies are involved in silicon production worldwide, most of them part of big chemicals conglomerates. They supply silicon to both the semiconductor and the solar energy industry. The companies most active in the manufacture of solar-grade silicon include *Hemlock (*USA), *Wacker (*Germany) and *Tokuyama* (Japan). In 2004 all three companies supplied a large proportion of their production to the PV industry and are also striving to expand these capacities further. In 2004 their combined production came to approximately 18,000 tonnes of polycrystalline silicon (polysilicon), with a target of more than 33,000 tonnes in 2010.

***REC* and *Solar Grade Silicon* as 'pure players' for solar-grade silicon**

The only company that has so far specialised exclusively in the production of solar-grade silicon is the US company *Solar Grade Silicon LLC (SGS)*, which is part of Norway's *REC Group*. In 2004 *SGS* produced 2,100 tonnes of solar-grade silicon, and plans to expand this capacity to 2,300 tonnes in 2005. A pilot plant with a capacity of 200 tonnes is currently in service, in which a new fluidised-bed reactor is being tested. If the results are positive, an additional 1,000 tonnes of production capacity could come on stream by 2007. There are plans to increase this to around 5,000 tonnes by 2010. As of the end of July 2005, *REC* also owns 75% of the US silicon producer *ASiMI* (*Advanced Silicon Materials LLC*), which has a capacity of 2,400 tonnes. This production will gradually be made available to the solar industry.

A newcomer to the scene is Norway's *Elkem*, which plans to produce solar-grade silicon using a metallurgical process. It hopes to produce around 2,000-5,000 tonnes next year. However, it's not yet certain whether the silicon really will be pure enough to meet solar industry requirements.

In addition *Joint Solar Silicon (JSSI)* – a joint venture between *Degussa* and *SolarWorld* – has produced its first prototype plant for making solar-grade silicon. Annual capacity should be in the region of 800 tonnes in 2007.

New association for solar-grade silicon

One very promising development is the newly founded European Solargrade Silicon Association. The purpose of this association is to invite tenders for solar-grade silicon production whose output will be destined solely for the PV industry. The founding members are *PV Crystalox*, *Deutsche Cell*, *SolarWorld* and *Schott Solar*. Membership of the association is open not only to the silicon processing industry, but to companies that produce solar cells and silicon.

Solar industry caught between booming demand and silicon supply bottleneck

The current industry situation is rather unusual: capacity utilisation is usually determined by demand, but this is not the case here. Demand for solar modules is robust and rising, but companies are still unable to increase their cell and module production capacities because there is not enough solar-grade silicon avail-

able. This shortage of raw material obviously gives silicon manufacturers the upper hand: they will be able to improve their margins over the next 2-3 years and consequently see their earnings rise dramatically. This will be to the detriment of end customers of solar systems, as it is almost inevitable that the higher silicon prices will be passed on down the value chain and ultimately forced onto by the end buyer.

Fig. 2: Production capacities for solar-grade silicon and maximum PV cell production

	2004	2005	2006	2007	2008	2009	2010
Solar-grade silicon production (t)	6'800	9'100	10'300	15'000	16'200	22'200	26'200
Inventories (t)	4'500	3'500	2'500	1'000	300	200	200
Scrap material from the semiconductor industry (t)	2'988	2'733	2'886	2'748	4'028	5'040	5'350
Total quantity available for solar industry (t)	**14'288**	**15'333**	**15'686**	**18'748**	**20'528**	**27'440**	**31'750**
Amount of silicon per Wp (t)	13.0	12.0	11.0	10.2	9.5	9.0	8.5
Total silicon-based PV cells (MWp)	1'099	1'278	1'426	1'838	2'161	3'049	3'735
Proportion of silicon-based PV cells	92%	91%	88%	89%	90%	91%	92%
Maximum potential PV cell production (MWp)	**1'195**	**1'404**	**1'620**	**2'065**	**2'401**	**3'350**	**4'060**
Potential PV cell demand (MWp)	1'320	1'603	1'944	2'336	2'702	3'182	3'848

Source: Sarasin, 2005

PV industry: expansion or vertical integration?

With raw materials in such short supply, larger producers of PV cells and modules obviously have a stronger negotiating position – in relative terms – and can exploit their purchasing power more effectively than the smaller players. We therefore expect that the major PV cell producers will be able to expand their market shares significantly in the coming years. There will also be a certain amount of industry consolidation. Under these circumstances a strategy of increased vertical integration by acquiring suppliers becomes more attractive, in order to secure better access to the desired pre-production materials (ingots and wafers). The companies that manage to anticipate the supply bottleneck in good time and make advance provisions for it will still manage to grow and capture a bigger share of the market.

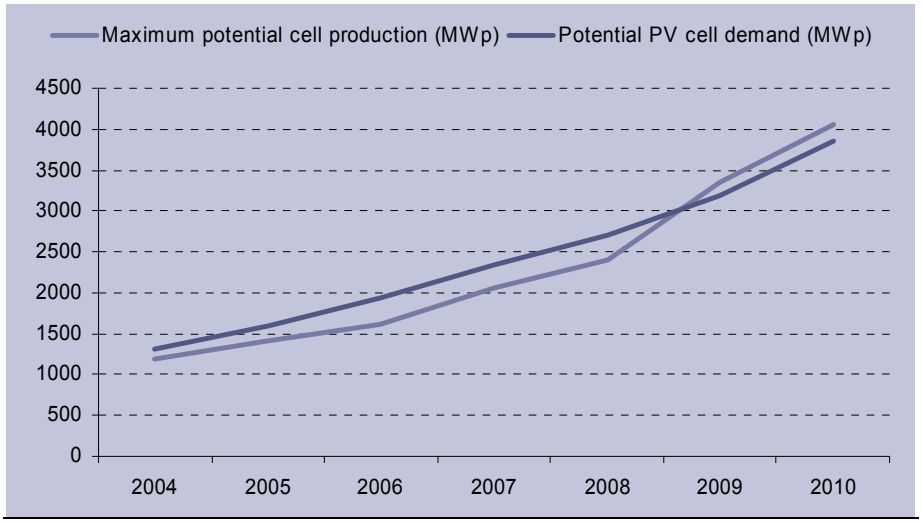
Supply shortage must not result in poorer quality

The industry agrees on one thing, however: on no condition may the current silicon bottleneck be allowed to compromise the quality of PV products. Rapidly organised but sub-standard raw materials would have disastrous consequences for the entire solar industry.

More efficient use of silicon and investments in alternative technologies

Because of the shortage of silicon, as well as for cost reasons, the PV industry is working hard to steadily reduce the specific amount of silicon required for each unit of capacity. Big efforts are being made to minimise scrap when sawing silicon wafers, to cut the wafers themselves more thinly, to increase the use of more direct production methods, such as EFG *(Schott)* or string ribbon *(Evergreen Solar),* and to develop more efficient solar cells. Similarly, alternative solar technologies not based on crystalline silicon will benefit in the long run from further increases in the price of solar-grade silicon. In the medium term it is in the solar industry's interest to build up an adequate supply of cheap silicon that is as independent as possible from the semiconductor industry. There is thus virtually no other choice for companies than to participate financially in a secured supply of solar-grade silicon.

Fig. 3: Silicon supply versus potential demand for PV cells (Sarasin forecast)



Source: Sarasin, 2005

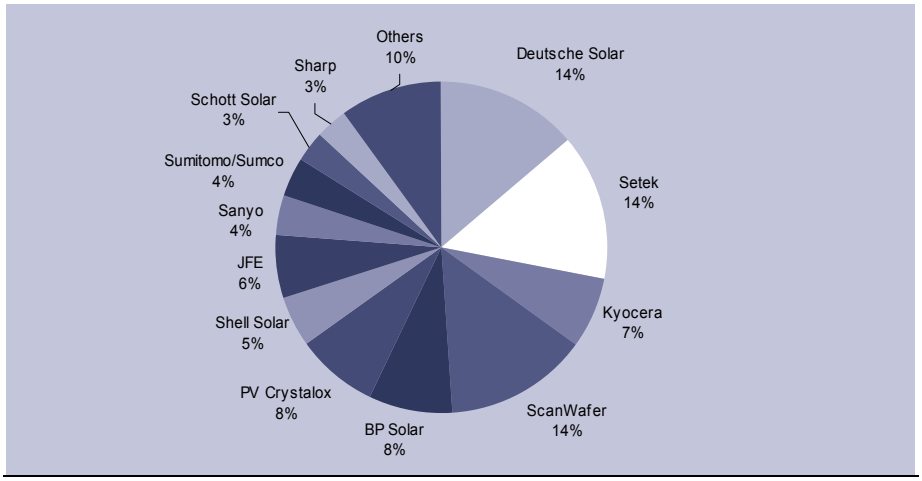
Wafer production

Wafer producers

The production of silicon ingots and wafers is frequently undertaken by the same companies. In 2004, IEA-PVPS estimated that wafers with a capacity of 860 MW were manufactured. According to IEA, the most important European competitors in this area are the Norwegian company *ScanWafer*, *Deutsche Solar* and *PV Crystalox*, an Anglo-German company. Figure 4 provides an overview of the leading wafer manufacturers for the photovoltaics industry. For 2005 we expect wafer production to total 1,300 MW.

Apart from wafer manufacturers, who sell their products to other solar cell producers, a number of companies are vertically integrated and make wafers primarily to meet their own requirements. The most important companies in this second category are *Deutsche Solar*, *Kyocera*, *BP Solar* and *Shell Solar*. Some competitors also use special technologies geared to their own solar cell production, such as the EFG method used by *RWE Schott Solar*.

Fig. 4: Market shares of leading wafer producers for 2005. Total capacity approx. 1,300 MW



Source: Prof. Dr. Peter Woditsch, Deutsche Solar, October 2005

Solar cells

Overview of PV cell production 2004

Review of solar cell production

Global production in 2004 was between 60% and 67% higher than in the previous year, depending on the data sources used. In last year's report we predicted global cell production of 1,125 MW for 2004. According to published figures, the volume was 1,195 MW[1] or 1,256 MW[2] (basis 2003: 750 MW). Apparently growth rates would have been even higher if producers had had even more raw materials available. Since 1995 annual growth rates for solar cell production have therefore averaged more than 35%, with photovoltaics comfortably beating the growth rates of other renewable energies such as wind power.

Module prices rising

There have been no further price cuts, due to the growing shortage of solar-grade silicon and the resulting bottlenecks in PV modules. Instead PV module prices have risen steadily over the last 14 months since June 2004. The increase was roughly 5% in the US and over 2% in Europe. This brought the average module prices of USD 5.22 per watt in America and EUR 5.75 per watt[3] in Europe to a level last seen in July 2003. At the moment, therefore, higher silicon prices can be passed on down the entire value chain. In the mid-term, however, prices should fall back into line with the annual 5% degression in the tariffs for renewable energy fed into the mains electricity grid.

The big PV cell production countries: Japan, Germany and the US

According to the latest figures from IEA PVPS[4], global solar cell production in PVPS countries alone jumped from 686 MW in 2003 to 1,109 MW in 2004, equivalent to growth of 62%. Production increased more than the average in Japan (+ 65% to 604 MW) and Europe (+71% to 329 MW), while production in the US "only" increased 35% to 138 MW (see Fig. 5).

Solar cell production in non-PVPS countries

Production in non-PVPS countries shows high percentage increases

According to IEA-PVPS, non-PVPS countries produced cells with a capacity of around 124 MW in 2004, an increase of 60 MW, or 93%, compared with 2003. This is a much higher growth rate than in PVPS countries. The figure of 124 MW now corresponds to roughly 10% of total global cell production of 1,233 MW.

China an important market and producer in PV business
-> Suntech Power
-> Baoding Yingli

The top country is China. The bulk of the Chinese solar industry consists of PV module producers, i.e. the part of the value chain that requires the least amount of know-how. Because labour is so cheap in China, solar modules can be built here more cheaply than anywhere else in the world. But China is also catching up in the area of actual cell production. Last year national cell production capacities climbed to 50 MW and production ran at 35 MW. Targets for the current year are additional production capacities of 100 MW for crystalline silicon cells and 240 MW for modules. Chinese PV module producers thus require substantial quantities of imported cells. Acquiring sufficient cell material will therefore be a major challenge for module producers. The supply of cells will in turn be

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1 Paul Maycock, PV Energy Systems, March 2005, www.pvenergy.com

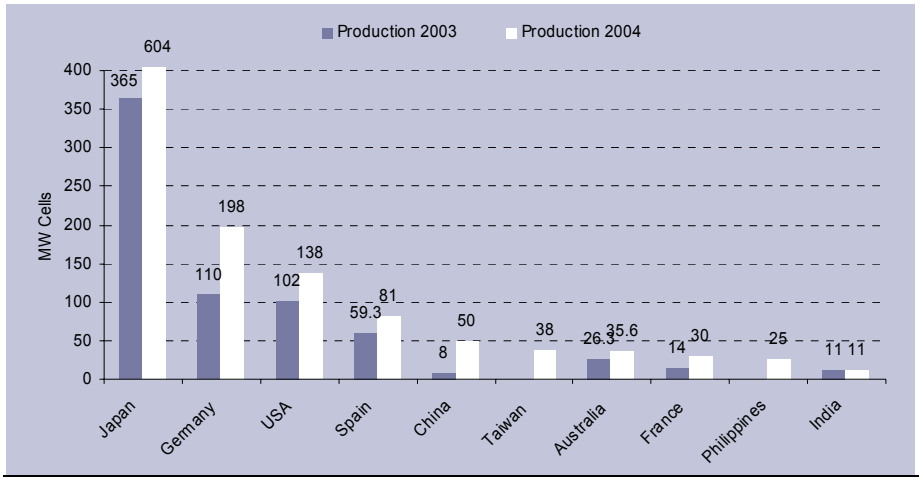
2 Photon, April 2005

3 www.solarbuzz.com/moduleprices: Solar module index excluding VAT

4 Trends in Photovoltaic Applications; Survey Report of selected IEA countries between 1992 and 2004. IEA Photovoltaic Power Systems Programme – Task 1; September 2005. All subsequent IEA-PVPS references refer to this publication. www.iea-pvps.org

restricted due to silicon bottlenecks. The Chinese are also working to resolve this problem. They plan to increase silicon production from the current level of 650 tonnes to at least 5,000 tonnes by 2010. All these figures clearly show that China will play an important role in the mid-term in the solar business, both as a producer and as a sales market.

Fig. 5: Country breakdown: Top 10 solar cell producers in 2003 and 2004



Source: IEA-PVPS and Sarasin, 2005

Taiwan -> Motech

In 2004 Taiwan produced PV cells with a capacity of 39 MW (35 MW monocrystalline and polycrystalline; 4 MW amorphous silicon), an increase of more than 100% on last year. Crystalline silicon cell production could even climb by as much as 140% to 85 MW by the end of this year.

Philippines -> Sunpower

The American company *Sunpower* has recently initiated cell production at a plant near Manila in the Philippines. In the second half of 2004 this plant produced the first high-performance cells with an efficiency ratio of more than 20%. Production capacity is set to increase to 50 MW by the end of the year.

India

India's solar cell market has stagnated in recent years and capacity is still around 10 MW per year (modules approx. 40 MW p.a.).

Top 15 solar cell producers

Top 15

The overview in Fig. 6 shows the world's top 15 PV cell manufacturers with the volumes they produced last year, estimated production in the current year, and planned capacities for y/e 2005 and 2006.

Sharp

The Japanese electronics group *Sharp* produced solar cells with a total capacity of 324 MW in 2004. In January 2005 *Sharp* also brought on stream two new production lines at its Katsuragi manufacturing plant, increasing its production capacity from 315 to 420 MW per year. These new lines can process wafers with a thickness of 180 μm. The typical thickness found in the industry is 270 μm. This new thinner wafer is not sawn from a silicon ingot, but produced direct from molten silicon using a die process. This allows *Sharp* to produce cells that save costs and materials. In addition, the company already makes a module with rear-contact solar cells (20% efficiency ratio). The market leader has also developed a concentrator cell with an efficiency ratio of 40%. PV modules are now being produced for *Sharp* in China as well, by *Shanghai Solar*, for example. Here *Sharp* provides the materials and also the "baking recipe" for its modules.

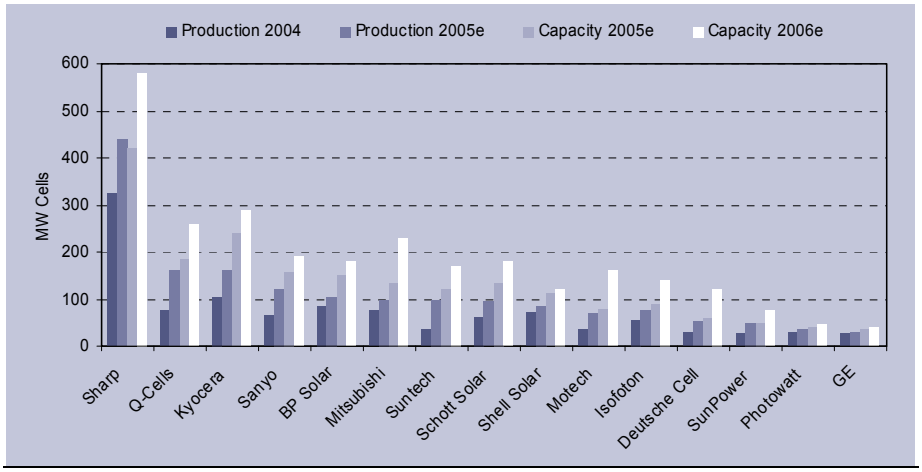
Q-Cells

In 2004 *Q-Cells* was Europe's biggest producer of solar cells, with a production volume of 76 MW. This year *Q-Cells* should continue to expand its market share and its estimated production of 162 MW should give it a global ranking of around second or third, compared with 11th place in 2002. Its planned capacity of 350 MW for 2007 would make *Q-Cells* clear number two after *Sharp*. At the start of October the company completed a successful IPO. *Q-Cells* has invested in the development of new technologies through joint ventures with partners in the US and Australia. In the first half of 2006 *EverQ*, its joint venture with the US company *Evergreen Solar*, is due to start production of solar cells using the string ribbon procedure, with an initial capacity of 30 MW. In its collaboration with the Australian company *Pacific Solar*, *Q-Cells* also plans to bring products to market in H1 2006 that were developed using the CSG thin-film process (CSG = crystalline silicon on glass). Both techniques use significantly less silicon than conventional applications.

Kyocera

Japan's *Kyocera*, the world's second biggest integrated solar company, produced solar cells with a capacity of 105 MW last year. The company plans to more than double its cell capacity to 240 MW in 2005, and has set itself the ambitious target of becoming the world's biggest fully integrated photovoltaics company. As of 2010 *Kyocera* only intends to mass-produce cells with a thickness of 100 μm.

Fig. 6: World's top 15 solar cell producers and their expansion plans, ordered by estimated production volume in 2005



Source: Photon, April 2005 and Sarasin

Sanyo

In 2004 *Sanyo* produced solar cells with a capacity of 65 MW. In response to the booming PV market, *Sanyo* has also announced its intention to increase capacities for its HIT technology (19.5% efficiency ratio) to 153 MW soon. Production capacity of amorphous solar cells is also due to be increased from 5 to 7 MW.

BP Solar

BP Solar, a wholly owned subsidiary of the global oil and gas giant *BP*, produced solar cells with a capacity of 85 MW in 2004. *BP Solar* is currently working on expanding its capacity to 200 MW by the end of 2006. It has production plants in the US, Spain, India and Australia. In Spain it plans to build new production lines to increase output to 50 MW p.a. In 2006 *BP* Solar wants to start building the world's biggest solar power station in Portugal. This project involves erecting

around 350,000 solar collectors on a greenfield site of 114 hectares producing a combined output of 62 MW by 2009.

Mitsubishi Electric

In 2004 the Japanese technology group *Mitsubishi Electric* produced solar cells with a total capacity of 75 MW. The annual output of the factories in Nakatsugawa and Kyoto were due to be increased from 90 MW to 135 MW by April 2005. By 2006 the company wants to build a production plant with a capacity of 230 MW.

Suntech

Suntech Power is a Chinese-Australian joint venture based in Shanghai that has only existed for three years and in 2004 already had a production capacity of 35 MW polycrystalline and monocrystalline solar cells. *Suntech* is therefore the first Chinese company to reach the top 10 list of solar cell producers. The company assembles most of these cells itself into proprietary solar modules. Capacity should reach 100 MW by the end of 2005. In January *Suntech* signed a contract with *SolarWorld* for the licensed production of solar modules that is worth EUR 100m over the next two years.

Schott Solar

On 1 October the specialist glass company *Schott* based in Mainz (Germany) bought out *RWE's* stake in the joint venture *RWE Schott Solar*. The company was renamed *Schott Solar GmbH*. Cell production came to around 63 MW in 2004. Capacity is being stepped up to 133 MW in 2005. One special feature is wafer production based on the "edge-defined film growth" (EFG) process which saves on material. The solar cell production plant in Heilbronn was taken over from *Solarwatt* in Dresden. The bulk of the high-performance PV cells produced at the new location have been supplied to *Solarwatt* for several years now. Over the next three years, production capacities in Heilbronn are due to be substantially increased from the current level of 6 MW.

Shell Solar

In 2004 *Shell Solar* produced solar cells with a capacity of 72 MW. In addition to modules made from crystalline cells, the company also produces thin-film modules based on a new generation of CIS technology. In 2005 total capacity should be some 110 MW.

Motech

Last year *Motech* produced around 35 MW crystalline solar cells in Taiwan. This year the figure is expected to be as high as 70 MW. A new factory with an annual production capacity of 120-200 MW should be ready by March 2006.

Isofotón

The Spanish solar energy company *Isofotón* produced cells with a capacity of 53 MW in 2004. Apart from Spain and Italy, *Isofotón* is active as a solar energy provider in 48 other countries. With a new plant in Malaga, the company plans to step up its annual cell production to 120 MW by the end of 2006.

SolarWorld (Deutsche Cell)

SolarWorld has manoeuvred itself into a very strong position overall. As an integrated solar company, it is especially well positioned when there are supply bottlenecks. *SolarWorld* already owns around 15% of global wafer production capacity – a secure internal source for its own cell production. *SolarWorld* also fosters close relationships with its suppliers, whether they be producers of raw silicon or companies that recycle scrap silicon. This source, coupled with scrap silicon from *Wacker Silitronic* actually covers more than 20% of the group's silicon requirements.

Deutsche Cell, a subsidiary of *SolarWorld,* produced cells with a capacity of 28 MW last year. At the start of the year, production capacities were expanded to 60 MW and are due to be increased to 120 MW by the end of 2006. At its site in Freiberg (Saxony) it wants to double annual wafer production to 240 MW by 2007 and more than double module production in Freiberg and Gällivare (Sweden) to 120 MW.

Sunpower

America's *SunPower Corporation* wants to expand its production capacity for solar cells to 50 MW by the end of the year. The new production line was installed at its Filipino subsidiary near the capital Manila. The building is designed to allow production to be expanded to 100 MW. In the coming years the company plans to install more production lines to bring capacity up to 75 MW. On the new line, production will be dedicated exclusively to the high-performance cell with an efficiency ratio of 21.5%. SunPower is one of the suppliers to Berlin's *Solon AG*, with whom it signed a USD 300m contract in April to supply high-performance cells over five years. In autumn *SunPower's* parent company, *Cypress Semiconductor Corporation* is expected to float *SunPower* on the stock exchange.

Photowatt (ATS)

The Canadian group *Automation Tooling Systems (ATS)* has a solar energy business called *Photowatt* that increased its capacity to 33 MW last year. Since the summer of 2004 it has been producing a new solar cell technology known as Spheral Solar Power (SSP). The factory is aiming for an annual capacity of 35 MW. It has highly automated production lines that manufacture flexible solar cells in different colours. SSP is based on crystalline silicon.

GE Energy

Astropower seems to have a new lease of life following its takeover by *GE Energy*. Last year *GE Energy* produced 25 MW, and this year the figure should be around 30 MW.

Other companies: ErSol, Evergreen Solar, Kaneka, Photowatt (ATS), Sunways

ErSol, a cell and module manufacturer based in Erfurt, produced cells with a total capacity of 16 MW last year and wants to increase this to around 28 MW this year. Capacity will be expanded to 50 MW by the end of 2005. At the start of October the company completed a successful IPO. By acquiring *ASi GmbH,* headquartered in Kreuzlingen (Switzerland), and setting up production in Arnstadt (Germany), *ErSol* is now active in the manufacture of ingots and wafers as well. The availability of silicon is secured into the next decade thanks to long-term supply contracts with well-known silicon manufacturers. *ErSol* is also conducting research, in collaboration with the Erfurt Solar Centre, on a flexible solar cell that is only 100 μm thick.

Evergreen Solar offers a patented string ribbon technology that provides attractive cost-savings potential in the medium term. Initially production capacity is set to increase to 15 MW by the end of the year. The company is examining ways of expanding this to 50 MW p.a. through a joint venture with *Q-Cells* (see above).

Last year the Japanese conglomerate *Kaneka* produced 17 MW amorphous silicon thin-film cells. These cells are only around 0.3 μm [micrometres] thick, compared with 200 μm for a normal crystalline silicon cell. The company's production target for this year is around 20 MW.

In September *Sunways*, headquartered in Konstanz (S. Germany) opened its new production plant for PV cells in Arnstadt (N.E. Germany). The 3500 m^2

production hall is designed for a capacity of 80 MW solar cells with an efficiency ratio of more than 18%. At the moment *Sunways* has a total production capacity of 30 MW. Last year the company only produced 11 MW. It also has a cooperation agreement with the machinery firm *Unaxis* in Liechtenstein, with the aim of jointly constructing within the next two years a production plant to make solar cells based on thin-film technology.

Sliver Cells from Origin Energy (AUS)

Origin Energy is Australia's second largest energy provider. Its recently launched solar cell is based on sliver technology developed in association with the Australian National University. This thin-film silicon cell is bifacial and captures light from the rear as well, which means its production only requires approximately 3 tonnes of silicon per MW. The first 10 W of Sliver modules were produced at the end of last year. Output is due to be increased to 40 W soon.

Leading Chinese producers Baoding Yingli and Nanjing PV-Tech

Apart from *Suntech Power*, China has a number of up-and-coming producers of PV cells. *Baoding Yingli* produced cells with a capacity of 10 MW last year. The company has an ambitious three-year plan designed to expand wafer, cell and module capacity to 300 MW by the end of 2007. By the end of this year *Nanjing PV-Tech* wants to begin operations at the first of three production lines with a combined capacity of 100 MW. Another production hall is ready to move into which would allow expansion up to 300 MW. But no decision has been reached yet on when to build these production lines, and the go-ahead hinges mainly on a secure supply of solar-grade silicon.

Silicon bottleneck prevents full utilisation of production capacities

At the moment most big solar cell producers are expanding their production capacities. In 2006 the top 20 companies alone would have a combined capacity of more than 3.5 GW, equivalent to around 95% of global cell production capacity. Past experience shows, however, that ambitious expansion plans are not always fully implemented, or tend to be delayed. Although demand is booming, the new capacities are still unlikely to be fully utilised because of the limited availability of silicon. As already mentioned, the companies who are most adept and successful at securing a supply of silicon should have fewer problems with capacity utilisation.

Solar cell technologies

Optimisation of industrial production still a top priority

Technological breakthroughs and announcements about record effectiveness and new materials in research are almost standard fare in the development of solar cells. But industry experts agree that the biggest challenges facing the solar industry are not primarily in the laboratory, but in the industrial-scale application of research findings. As far as manufacturing processes are concerned, there is still a lot of room for improvement from a technical and commercial viewpoint. Over the coming years the top priority is therefore still likely to be the optimisation of manufacturing processes in order to reduce costs.

Silicon-based cell technology continues to dominate

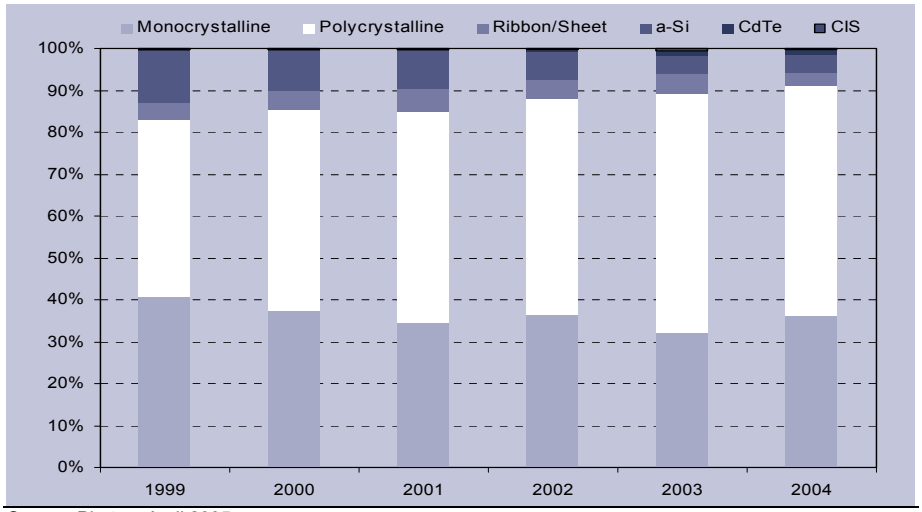
In 2004 the picture for cell technologies was pretty much unchanged. Almost 90% of all solar cells produced are now mono or polycrystalline silicon cells. They still offer the best price/performance ratio. The enormous growth of recent years was mainly due to these technologies (see Fig. 7). String ribbon cells, as manufactured by *Schott Solar* and *Evergreen Solar*, may soon become more popular because less silicon is used in their manufacture. Despite an increase in

production output, thin-film technologies (amorphous silicon, CdTe, CIS, etc.) were unable to keep pace with the market.

Despite optimisation, significant cost savings only possible with new technologies

We think the shortage of silicon will encourage the development of more efficient technologies. In crystalline silicon technology, the focus is on thinner wafers with bigger dimensions and improved efficiency. Most providers are not attempting to make any fundamental changes in the design and manufacture of cells, and have still managed to achieve significant progress so far with this strategy.

Fig. 7: Market shares of different solar cell technologies



Source: Photon, April 2005

Technological innovation across a broad front

The second strategy manufacturers pursue is to research innovative materials and technologies and try them out in pilot production. These initiatives entail a lot of research and considerable risks, but they also potentially offer big cost savings in the long run by substantially improving efficiency ratios. Innovations include, for example, ultra-thin crystalline cells, tandem and concentrator cells or organic solar cells.

The major PV markets

Installed PV capacity up 62%

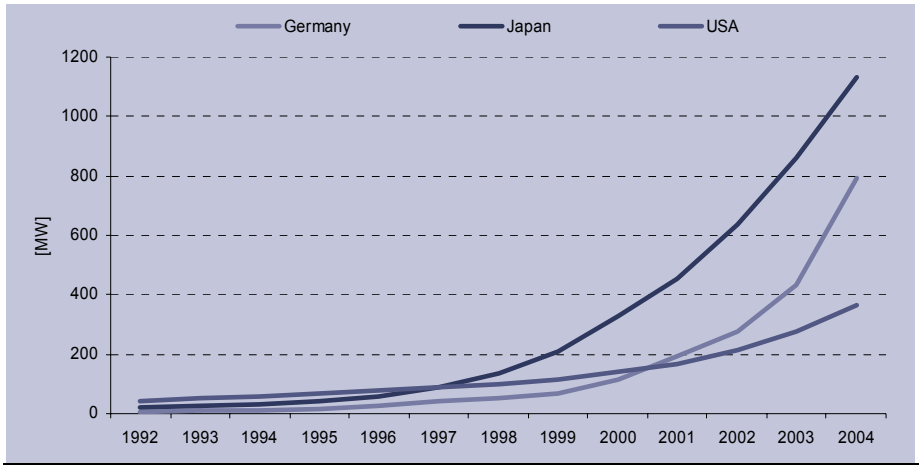
Preliminary comment: In contrast to information provided previously about the quantities of solar cells produced, in what follows we are dealing with PV capacity actually installed in the form of PV systems. According to IEA-PVPS, globally installed PV capacity reached approximately 840 MW in 2004 (PVPS countries 770 MW + non-PVPS countries 70 MW) while the market report published by Solarbuzz put the figure as high as 927 MW. This is equivalent to growth of 43% (or 62%) on last year.

Germany takes over the lead from Japan

Last year Germany overtook Japan with growth of 137%, to achieve 363 MW of newly installed capacity. In Japan 272 MW were installed last year, an increase of 22% on 2003. These two countries now account for 68% of globally installed PV systems. In 2004 growth in the US came to 43%, to reach 90 MW newly installed capacity. The dominant nations in installing PV capacity are still Germany, Japan the US (in that order). Together they accounted for roughly 86% of the newly installed global capacity in 2004. These countries have dominated the industry for years, as reflected in the cumulative totals for installed capacity. Here Japan leads the way (1,132 MW), followed by Germany (794 MW), the US

(365 MW), and then – after a big gap – India (86 MW), China (70 MW), Australia and the Netherlands (both 50 MW). The historical comparison between the three big players highlights the explosive growth in Germany, which has been fuelled during the last two years especially by attractive tariffs paid for renewable energy fed into the mains electricity grid (see Fig. 8).

Fig. 8: Historical development of cumulative PV capacity installed in the three biggest markets: Japan, Germany and the USA



Source: IEA-PVPS, 2005

Analysis of top three PV markets: Germany, Japan and the US

The next section takes a closer look at the dominant PV markets of Germany, Japan, and the USA and describes the overall conditions that significantly influence PV demand in these countries.

Germany

German PV market takes the lead

Last year Germany's PV market experienced explosive growth, with 363 MW of newly installed capacity. This is equivalent to 173% growth on last year (133 MW). According to figures published by the German solar industry association (BSi), cumulative installed capacity already passed the one gigawatt threshold in the first half of 2005. The new feed-in tariffs following the revision of the Renewable Energy Act (EEG) gave the market the required boost and stability. Since the summer of 2004 booming demand can no longer be satisfied, and delivery times of six months are commonplace.

Renewable Energy Act provides crucial stimulus

At the moment solar energy installations pay for themselves purely thanks to the attractive tariffs paid for renewable energy fed into the mains electricity grid. The strong market growth and the bulging order books of module producers show that people are very keen to invest in modern green technologies if the financial incentives are attractive enough. Apart from this purely financial aspect, solar energy also benefits from the very high acceptance of renewal energies among the general public.

Massive capacity expansion by producers of modules and cells

In the past five years German manufacturers have invested a total of more than EUR 1.5 billion in building up new capacities for PV cell and module production. According to information from German providers, this production capacity is set to double again by the end of 2005. German manufacturers still have faith that the PV boom will continue.

Grand coalition

The change of government following premature elections most probably does not signify any dramatic worsening of the conditions for government subsidies. A consensus still exists between the two coalition parties concerning the promotion of solar energy, particularly since approximately 30,000 people are now employed in Germany's solar industry.

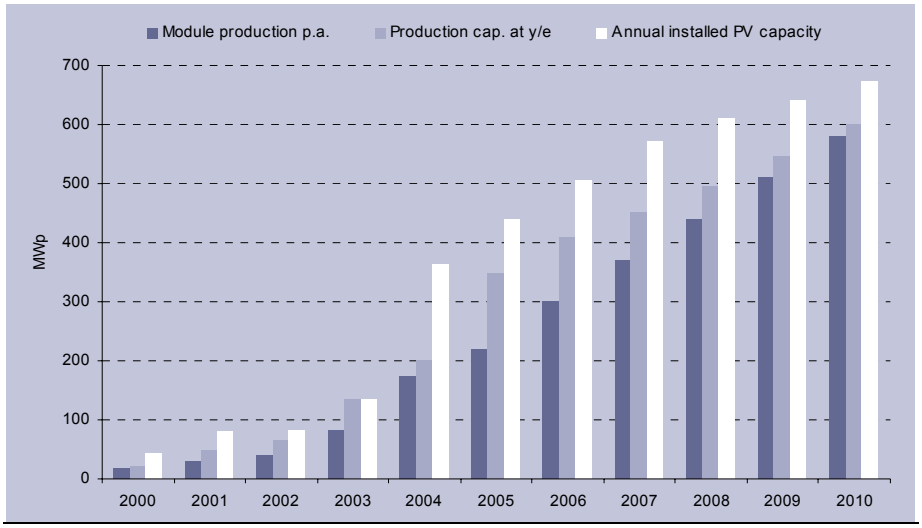
Export business increasingly important

Irrespective of what happens with the new government, it would be wise for Germany's solar companies to use the period up to 2007, when the next regular review of feed-in tariffs is scheduled, to reduce their dependency on the German market by building up their export business. Important export markets include Spain, Portugal, France, Italy, Greece and Cypress. Some of these countries have also created subsidy programmes for solar installations. The growing market potential of India and China should also provide attractive opportunities for German solar companies. Our forecast shows a gradual convergence between German production and installed domestic capacity (see Fig. 9). It is therefore essential for the German solar industry to expand its international distribution network and significantly increase its export quota.

Short and mid-term forecast for the PV market in Germany

In view of the expansion plans of German module producers, we expect production capacities to rise over the next three years from 200 MW (y/e 2004) to 350 MW (2005) and almost 410 MW (2006). Over the same period module production is set to increase from 174 MW (2004) to 300 MW (2006). If we add up the 2006 capacity forecasts published by the module producers, total production capacity would work out at around 600 MW. Companies would therefore be well advised to carefully review their capacity expansion plans. Otherwise they will find it difficult to maintain in the long run the 100% capacity utilisation that many of them currently enjoy, especially in view of the shortage of solar-grade silicon discussed previously. We expect slightly moderated growth in the number of installed systems in Germany. Annual newly installed capacity is likely to rise from 363 MW (y/e 2004) to 440 MW (+21% in 2005) and 505 MW (+15% in 2006).

Fig. 9: Short and mid-term forecast for the PV market in Germany



Source: BSi, IEA-PVPS 2005, company information and Sarasin estimates

The circle of listed solar companies is growing

Investors have benefited from Germany's solar boom as well. Shares in German solar companies have been surging ahead in recent months. Many companies seem to want to take advantage of the industry's positive trend to float on the

stock market. After *Conergy* made a strong debut this year, companies such as *Q-Cells, ErSol* and others have followed suit.

Germany as a driving force for achieving EU targets for renewables

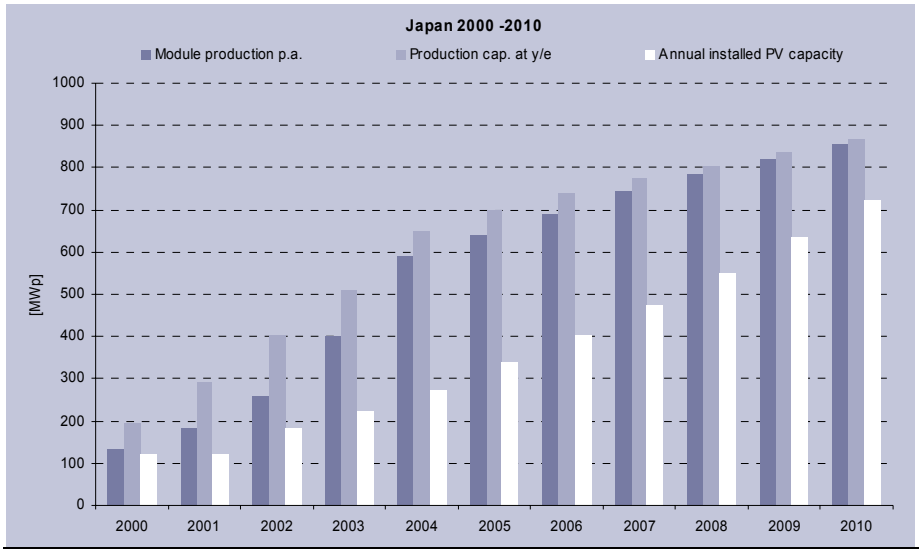
Very ambitious targets have been set in Germany for the growth of the PV market over the longer term, both on the part of the government and the industry associations (which are naturally more optimistic). Germany acts as a role model for the achievement of the goals set by the EU for renewables in its White Book in 1997: the percentage of renewables used is to be doubled from 6% to 12% by 2010 across the whole of Europe. To achieve the target in 2010, growth has to continue at a rate of more than 30% p.a. This is an ambitious goal, and one that requires other countries to expand their photovoltaics as significantly as Germany.

Japan

Solar energy as a constituent of overriding energy targets

In Japan, incentives to promote photovoltaics are an integral part of national energy policy. In sharp contrast to the US, the Kyoto protocol also plays a very important role. The government is committed to achieving a 7% reduction in 1990 CO_2 emissions. Photovoltaics have been singled out as a means of achieving this reduction. The *Ministry of Economy, Trade and Industry* (METI) wants 10% of energy requirements to be met by renewables by 2030, with half of this (approx. 100 GW) coming from photovoltaics. A more concrete interim target of 4.8 GW installed PV capacity has been set for 2010.

Fig. 10: Short and mid-term market forecast for Japan



Source: up to 2004 IEA-PVPS, from 2005 Sarasin

RPVD programme ends in March 2006...

The successful *Residential PV System Dissemination Programme* (RPVDP) to promote PV systems for private houses has made Japan a leader in PV in recent years. Despite falling lower subsidies for each solar system installed (JPY 900/W in 2003; JPY 450/W in 2004, JPY 20/W in 2004), Japan has found a good balance between costs for individual consumers and state spending. Seemingly the RPVD programme had already used up the entire subsidies available by the end of September – well before its official end in March 2006. It's not yet clear what will come after that. At the same time there are a number of local programmes whose future is also uncertain. Japanese utility companies have also announced that they would only extend their voluntary *Net-Metering System,* which compen-

sates customers for feeding solar energy into the mains grid, if the government maintains its PV subsidies.

... but PV systems for public buildings will be promoted instead

Instead of subsidising PV system for residential buildings, the METI is planning a programme of subsidies for 30-50 kW systems mounted on public buildings, schools, factories and office premises. Full details and a budget proposal will be submitted this autumn.

There was no fall in the number of applications for funding from the RPVD programme even in the last year of its existence, despite the fact that its degressive tariffs meant it only provided a 3% subsidy (JPY 20/W) towards installation costs. This is strong evidence to suggest that the Japanese market for smaller PV systems owned by private customers can now be classed as virtually self-sufficient.

Heavy export pressure likely

In 2004 Japanese capacities for PV module production were around 650 MW. On the other hand, 273 MW new capacity was installed in Japan itself. This massive "capacity overhang" shows the strong export bias of Japanese producers, which is set to increase over the next 2-3 years. But the export business also carries risks: because Germany's PV cell and module producers will soon outgrow the limits of their home market as well, pressure will inevitably mount on margins unless other countries take over the role of growth motor from Japan and Germany by then, and absorb the anticipated surplus production. Annual newly installed capacity is likely to rise from 273 MW (y/e 2004) to 340 MW (+25% in 2005) and 405 MW (+19% in 2006).

USA

Installed capacity up 43%

So far there has been no federal programme of subsidies for solar energy in the US. Some subsidies are available in individual states. This relatively modest support is also the reason why growth in the US has lagged Germany and Japan. Even so, 90 MW of new capacity was installed in 2004, which is equivalent to 43% growth on 2003.

Bush's Energy Bill – Solar industry gets a sweetener

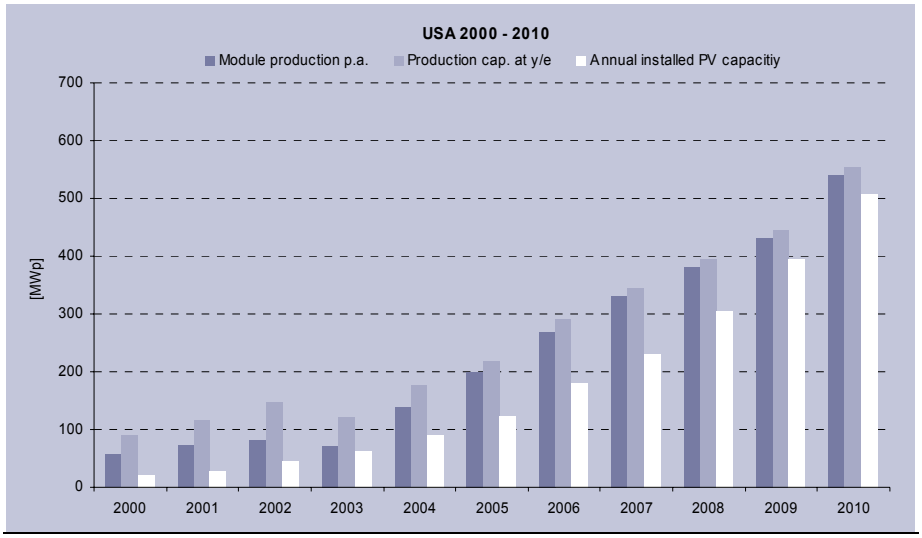
In August Congress passed a new Energy Bill offering investment tax credits (ITC) worth 30% of investment costs for commercially operated solar systems. This programme is due to start in January 2006. Private operators also receive a tax credit of 30%, but only on investments up to USD 2,000 per system. However, this subsidy applies to all forms of solar energy: both photovoltaics and solar thermal power. Since the incentive only runs to the end of 2007, the US solar industry (as well as the wind power industry) will be obliged to constantly fight for these investment tax credits to be extended. The new time limit will therefore do very little to encourage the expected security of investment, especially since for many Americans this incentive will not be enough to persuade them to purchase a solar system. For this to happen, individual states need to offer programmes with specific subsidies as well. The Energy Bill passed by Bush is therefore unlikely to trigger a PV boom in the US for the time being.

Hold-ups in California's support for solar power

Many people were also hoping for a new public subsidy programme in California, where the planned "Million Solar Roofs" programme is currently being delayed and watered down. Trade unions demanded a change so that only highly qualified electricians are allowed to install solar systems. But such a move would inflate installation costs and virtually cancel out the tax credit. Governor Schwar-

zenegger has recognised this threat and vetoed the law. Unfortunately this puts the entire programme on ice for the time being. Interest in solar energy has traditionally been very high in California, and last year almost half of America's entire PV capacity was installed in this state. Electricity consumption is particularly high in the summer in this region, when air conditioners are turned up high. Solar energy can meet this need very well, as it is particularly suited to dealing with this type of peak load.

Fig. 11: Short and mid-term market forecast for the US



Source: up to 2004 IEA-PVPS, from 2005 Sarasin

In the entire USA there are more than 50 different PV programmes of individual federal states and utility companies. However, these fragmented measures have not had the same sweeping effect as the unified subsidy mechanisms in Germany and Japan. The key to the US solar market therefore still lies in California.

Cell and module production pick up again in 2004

Last year cells with a capacity of 138 MW and modules with a capacity of 139 MW were produced in the US. After production fell in 2003, it picked up again by 35% in 2004, while module production rose as much as 95%. This fosters the hope that the trend will turn positive again. For 2005 we forecast newly installed capacity of 125 MW (+39%) and 2006 a capacity of 180 MW (+44%).

Other important markets

Spain has attractive conditions for solar energy

Good conditions for a future booming market exist in **Spain**, which has now introduced feed-in tariffs for renewable energy that are even more attractive than Germany's. Spain currently offers a tariff of EUR 0.42 per kWh for PV systems under 100 kW and a rate of EUR 0.22 EUR for systems with an output of over 100 kW (incl. solar thermal power stations), payable over a period of 25 years. After that, 80% of the tariff is paid until the end of the system's working life. Soon the threshold for the programme is due to be raised from the current level of 150 MW to 400 MW for PV systems and from 200 MW to 500 MW for solar thermal power stations. Some initial teething problems led to certain bureaucratic obstacles, and made the formulation of the legislation more complicated. But Spain is obviously a very attractive country for solar energy because of its ample sunshine. Last year 10 MW of new capacity was installed (+53%). Interestingly, almost half the installations were greenfield sites (solar parks). Just recently Euro-

pressedienst conducted a detailed study of Spain's photovoltaics market.[5] Its forecast for installed PV capacity is 265 MW by 2010. Our estimates are around 228 MW, with an average annual growth rate of 68% over the period 2004 to 2010.

Italy also has feed-in legislation

In **Italy** systems up to 20 kW are entitled to a feed-in tariff of EUR 0.445 per kWh, while those with an output between 20 and 50 kW receive EUR 0.46 per kWh. Systems above 50 kW and up to a limit of 1 MW have to submit a tender, and can receive a maximum reimbursement of EUR 0.49 per kWh. These tariffs initially apply for 2005 and 2006, and then drop by 2% every year for new systems. The amount of subsidised PV capacity is expected to be roughly 100 MW by 2015, but can be increased to 300 MW if the ceiling is already reached before then. However, the law is based on a confusing mix of different incentive systems (net energy fed in, invitation to tender, reimbursement, etc.) and will take time to make an impact. Our estimates are for 73 MW of newly installed capacity in 2010, with an average annual growth rate of 58% over the period 2004 to 2010.

Portugal soon to have the world's biggest solar installation

Feed-in tariffs have also been recently revised upwards in **Portugal** as well. Tariffs are currently EUR 0.41 per kWh for systems under 5 kW and EUR 0.244 per kWh for those over 5 kW. The government is aiming for 150 MW of installed power up to 2010. But this figure could be far higher considering that the system planned by *BP Solar*, and due to be connected to the grid in 2009, will boast a capacity of 62 MW.

South Korea also has a feed-in tariff

South Korea is a very promising growth market for solar energy. As a country with few natural resources, South Korea's government is attempting to reduce its dependency on oil imports by introducing an attractive programme of market incentives to encourage the expansion of renewable energies. As in Germany, the construction of solar systems is being encouraged with tax credits and every kilowatt hour of solar energy fed into the mains grid is reimbursed at a tariff of 58 cents, a rate guaranteed for 15 years.

Installations in developing and newly industrialised countries

Where does the future of photovoltaics lie?

It's important to remember that despite the huge boom in Germany, electricity from PV installations still only makes up a relatively small share of total electricity consumption. Since at our latitude we can expect around 800 kWh per kWp per year, the 1,000 MW capacity accumulated in spring results in an electricity output of approximately 0.8 billion kWh (0.8 TWh). By comparison, Germany's annual electricity consumption is around 500 TWh. Solar energy therefore accounts for less than 0.2%. Again, by way of comparison: Last year hydroelectric power contributed 21 TWh, and wind energy as much as 25 TWh.

Development in non-PVPS countries

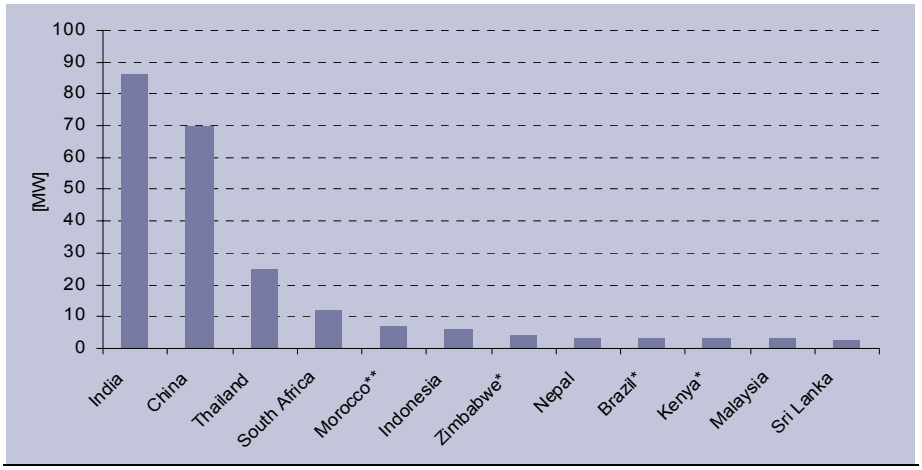
According to information from IEA-PVPS, the use of photovoltaics in countries outside the OECD, or non-PVPS countries[6], is mainly limited to smaller residential systems (solar home systems) and applications on public buildings such as

[5] The Spanish photovoltaics market 2005/06 – Risks and opportunities of up-and-coming export markets; Europressedienst EuPD, Bonn, September 2005

[6] OECD countries that are not PVPS members: Belgium, Czech Republic, Finland, Greece, Hungary, Iceland, Ireland, Luxembourg, New Zealand, Poland, Slovakia and Turkey.

hospitals, schools, water utilities and telecommunications. Off-grid PV systems are the main application in developing and newly industrialised countries (see Fig. 12). In total non-PVPS countries already had over 230 MW capacity (cumulative) installed in 2004, equivalent to roughly 9% of the 2,600 MW PV capacity installed in PVPS countries.

Fig. 12: Total installed PV capacity (cumulative) in non-PVPS countries



Source: IEA PVPS 2005; figures from 1999*, 2003*, otherwise 2004

India in fourth place for off-grid PV systems

With a cumulative capacity of around 86 MW, India is number four in the world rankings behind the big three – Japan, Germany and the US. Already more than 320,000 solar home systems (SHS) have been installed with subsidies from the government's PV programme. The government's target is 280 MW of capacity by 2012, including solar thermal installations.

China forging ahead with photovoltaics

China's cumulative capacity has trebled since 2001 to approximately 70 MW, boosted especially by a National Township Electrification Programme (SDDX). By the end of the year, more than 600 towns are to be supplied with 16 MW solar power under the programme. SDDX will be followed next year by a National Village Electrification Programme (SDDC) which will install 265 MW of solar energy in 10,000 villages by 2010. In January 2006 a Renewable Energy Act should provide a further boost for photovoltaics through feed-in tariffs and attractive tax credits. The feed-in tariffs for the individual technologies are still being haggled over. We expect China to install more than 200 MW per year up to 2010.

Thailand sets itself goals for PV expansion

Thailand also wants to achieve installed capacity of 250 MW by 2011. To this end the government has set up a "Renewable Portfolio Standard" programme which alone should contribute 200 MW in capacity.

Off-grid PV systems are the future

The above examples show that developing and newly industrialised countries will be important markets for photovoltaics in future. In these regions some two billion people have no access to mains electricity. Small decentralised solar home systems (SHS) or PV hybrid systems for supplying electricity to villages are often the quickest and cheapest way to substantially improve the living standards of predominantly rural populations. Not just PV cell and module manufacturers, but the entire business of solar systems technology stands to benefit from this huge sales market. Export markets for rural electrification programmes encompass the financing, supply, installation and operation of off-grid power plants.

The insert in the next box outlines the special criteria that have to be met in order to exploit this enormous potential:

Criteria that PV systems have to meet for use in non-OECD countries

Selling PV systems to developing and newly industrialised countries carries certain risks for all parties involved. Ultimately photovoltaics are certainly the cheapest solution in rural areas, because the energy requirement of each individual is so small that it is not economical to install or extend a mains supply. But the direct purchase of a PV system by the end users is usually not an option either, as they do not have the necessary financial means. Many of them are used to spending USD 3-10 of their tiny household budget every month on candles, kerosene or batteries. But there is seldom any financial institution available to offer micro credit (USD 300-500) for such a major investment. Another stumbling block is the creditworthiness of the end user. This problem can be solved with the help of international development agencies, such as the *KfW development bank* or the *World Bank*.

Another obvious difficulty is that even though the technical quality of the systems may be good, minimum regular maintenance is still required and this has to be organised locally. To be successful in this market, companies therefore need adequately qualified local staff. The cost of training these people cannot usually be recouped through the sale of PV systems. In this case close collaboration between the industry and institutions for technical collaboration, such as *GtZ* or *KfW*, can be of mutual benefit. With this in mind, the industry association *Club for Rural Electrification* was set up in 2000 under the leadership of the *Fraunhofer-Institut Solare Energiesysteme ISE* in order to promote rural electrification through renewable energies.

One of the defining characteristics of successful rural electrification projects is therefore that sufficient consideration is also given to social aspects and to the fact that ultimately advanced technology will need to be integrated into a society that is not usually technically oriented. This market holds enormous potential for the solar industry. Simply supplying 1% p.a. of the non-electrified population with 10 W of power per person equates to a market volume of 200 MW per year. If, taking into account all the components and services, we assume a price of roughly EUR 10 per watt in an off-grid PC system, this corresponds to potential annual sales of EUR 2 billion.

Felix Holz, Fraunhofer ISE, Institut Solare Energiesysteme, Head of Group Off-Grid Power Supply Systems, Freiburg (Germany).

PV market trends up to 2020

Approx. 1,100 MW of new capacity installed in 2005

According to our estimates, around 840 MW of new PV capacity was installed in 2004 and this year the figure will be around 1,100 MW. This is equivalent to a growth rate of 30%. Our long-term forecast shows the development of **new PV capacity installed globally every year,** rather than annual PV cell production (as in last year's report). We based our forecast on the market estimates for the most important countries. The historical data are based on information from IEA-PVPS. The annual comparison shows that the PV capacity actually installed is much lower than the figure for solar cell production. One plausible explanation for this, however, is the time lag between the production of PV cells and the installation of complete PV systems, at the same time as growth rates are soaring.

2010: newly installed PV capacity of 3.0 GW

This year, and in the next 2-3 years, the installed capacity will be curbed by the availability of PV modules, which is in turn due to the shortage of solar-grade silicon. The silicon supply bottleneck should improve after 2008. For 2010 we forecast around 3.0 GW of newly installed PV capacity worldwide. This corresponds to an average annual growth rate of 23.6% for the period 2004-2010.

Fig. 13: Sarasin forecast for national PV markets (newly installed capacity p.a. in MW)

Newly installed									CAGR
	2003	2004	2005	2006	2007	2008	2009	2010	04-10
Germany	153	363	440	505	571	611	641	673	10.8%
Italy	4	5	9	15	23	34	51	73	58.1%
Spain	7	10	22	30	45	77	134	228	68.3%
Rest of Europe	35	17	26	32	35	40	46	58	22.5%
Europe	**198**	**395**	**497**	**582**	**673**	**761**	**872**	**1032**	**17.4%**
USA	**63**	**90**	**125**	**180**	**230**	**304**	**395**	**506**	**33.4%**
China	11	30	55	70	98	142	213	330	49.2%
India	16	20	35	40	54	73	106	159	41.2%
Japan	223	272	340	405	474	551	634	724	17.7%
Rest of Asia	5	14	21	26	38	55	85	131	46.1%
Asia	**254**	**336**	**451**	**541**	**664**	**820**	**1038**	**1344**	**26.0%**
Rest of the world	15	23	32	37	43	58	81	123	32.0%
Newly installed capacity p.a.	**531**	**844**	**1105**	**1340**	**1611**	**1944**	**2386**	**3005**	**23.6%**
Annual growth rate	48%	59%	31%	21%	20%	21%	23%	26%	

Source: IEA-PVPS figures up to 2004, Sarasin estimates

Shift in regional emphasis

Germany and Japan will become less important PV markets in relative terms, as their current prominence inevitably starts to wane. Our estimates show that Germany's share of the global market, for example, will gradually drop from 43% (2004) to 23% (2010), and Japan's from 32% to 24%. Other European markets such as Spain, Portugal or Italy, all of whom have a low starting level, will become increasingly important. In Asia, China, India, South Korea, Taiwan and Thailand will be the biggest winners and develop into important PV markets.

Off-grid systems becoming more important

At the moment grid-connected PV systems dominate, especially in the major markets of the industrialised world. But with the Asian markets growing so rapidly, along with developing and newly industrialised countries, off-grid systems will become increasingly important. The solar industry therefore needs to develop more products specifically for these markets and their applications.

Main risks for the PV market

The following factors present risks that could constrain the anticipated positive development of the PV market:

- **Persistent shortage of solar-grade silicon.** Failure or delay in tackling the expansion of production capacities up to 2008 and beyond in a systematic way. This will prolong the silicon bottleneck.
- **Delays or changes to important subsidy programmes**. The solar industry is still heavily dependent on a number of individual markets where photovoltaics are still supported by subsidy programmes.
  - The change of government in Germany poses a certain risk. However, we do not expect to see any significant amendment to the Renewable Energy Act until it comes up for regular renewal in 2007.
  - Further delay to California's "Million Solar Roofs" programme could postpone the expected boom in the US market.
  - Critical transition phase in Japan: It's not clear yet whether the Japanese market is fully developed enough to cope with the loss of subsidies when the PVRDP runs out in 2006.

- **Higher interest rates.** Because of the high capital costs associated with PV systems, rising financing costs due to higher interest rates exert their full impact on total costs, which could dampen demand. This is particularly true for commercial operators of PV systems.
- **Increasing competition** from their own camp in the form of alternative solar technologies such as solar power stations (see chapter 3).

Threatening energy crisis implies upside potential

Diminishing resources and soaring prices in the oil market could promise additional upside potential for solar energy. There has been a marked increase in governments' willingness to promote renewable energies through incentives such as feed-in payments or tax breaks. In addition, conventional energy production is generally becoming more expensive, so the gap with solar energy is narrowing.

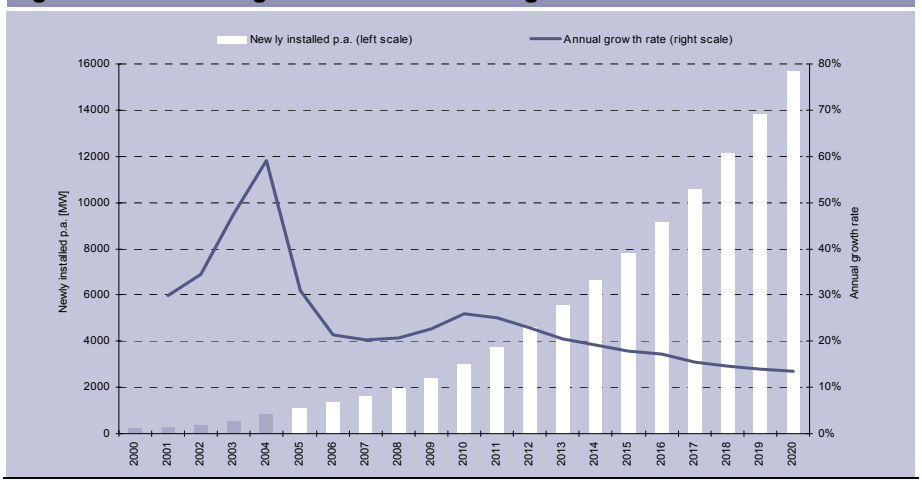
In the field of hybrid systems, photovoltaics can either replace or supplement diesel generators. Here the price of oil has a direct influence on demand for PV systems. This market is limited mainly to the USA and developing countries, and is only of secondary importance compared with the currently dominant grid-connected applications.

For thermal solar energy use, the costs of fossil alternatives (usually heating oil) are an even more important factor than for photovoltaics. This economic substitution mechanism is showing its first measurable results, since the oil price has been so high for a long time and because people think it will remain at that level.

Conclusion: Modest but steady growth over the longer term

In the longer term, however, the opportunities afforded by photovoltaics are still far from being exhausted. The easing of growth rates caused by the silicon bottleneck helps to prevent the market from overheating and therefore encourages healthy growth in the long run. We expect costs to be significantly reduced as a result of advances in manufacturing methods (bigger units, automation) and various new technologies reaching market maturity. This should allow production capacity to revert to the growth path it has shown since the end of the nineties. According to this scenario, the annual installed capacity will therefore more than quadruple from 3.0 GW in 2010 to around 15.5 GW in 2020. This is equivalent to an annual average growth rate of 18%.

Fig. 14: Sarasin's long-term forecast for the global PV market



Source: Sarasin, 2005

Assessing the sustainability of PV systems

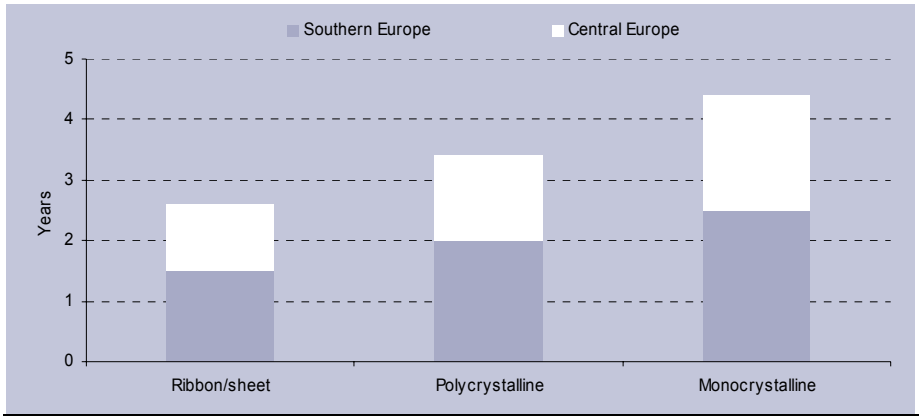
It is frequently assumed that renewable energies must, *a priori*, be sustainable. The manufacture of PV cells in particular is an energy-intensive process that uses a lot of chemicals, and it is therefore worth taking a closer look at this issue.

EU project "Crystal Clear" confirms PV systems' short energy payback times

An EU project conducted in this area under the name "Crystal Clear"[7], which runs to 2008, is currently examining the entire life cycle of the PV cell from the silicon raw material to the finished PV module. The aim is to reduce the production costs for solar modules by approximately 60%. The intention is also to try and cut the energy payback time from the current 3-5 years to just two years. Before this could happen, more up-to-date figures had to be collected, as all studies on the subject of energy payback times of crystalline solar systems had previously been based on a study published in 1992 by the Munich energy research institute *Forschungsstelle für Energiewirtschaft*. This was in turn based on German production lines using technology developed in the eighties.

Preliminary Crystal Clear results, which were presented in June at the 20th European Photovoltaics Conference in Barcelona, show an improvement of around 25% in energy payback times compared with five years ago. This is mainly attributable to advances in the efficient use of the silicon raw material. Further improvements are anticipated with the wafer thickness being reduced to 150 μm. The project examined solar modules with polycrystalline and monocrystalline cells and modules with string ribbon cells. With the latter type of cell, there is no sawing of the wafer, thereby resulting in highly efficient use of silicon, which is a very energy-intensive material. The energy payback time for PV systems in Central Europe (750 kWh/kW) is 2.6 to 4.4 years, and for Southern Europe (1,275 kWh/kW) 1.5 to 2.5 years.

Fig. 15: Energy payback time for modern solar systems (preliminary results)



Source: EU Crystal Clear project, 2005

The environmental rating of photovoltaics is determined not only by the energy payback time, but also by the disposal and recycling problem. The PV industry is not directly affected by the new European environmental directives WEEE and RoHS[8] . Even so, a preliminary warning needs to be sounded.

[7] Project results can be found under: www.chem.uu.nl/nws/www/publica/E2005-32.pdf

[8] www.bmu.de/elektrogesetz

WEEE directive

The WEEE directive (waste of electric and electronic equipment) makes it compulsory for the industry to take back used electronics products. At present PV modules are explicitly excluded. But solar-powered calculators, clocks, etc. already fall under the directive. It is quite feasible that the legal situation could change once photovoltaics develop from a niche product into a mass-produced technology.

Initial initiatives are already under way for the recycling of solar modules. *Deutsche Solar* has set up a recycling plant and feeds the recovered solar-grade silicon back into its production process. Although the procedure for recycling wafers is rather laborious, it makes both environmental and financial sense because of the high manufacturing costs and the general shortage of raw material. Fragments of cells cannot be worked up directly into wafers, but first have to be melted and formed into silicon ingots. This leads to high energy consumption and substantial material loss. On the other hand, the recycled wafers can now also be produced in bigger dimensions.

First Solar also takes back its CIS cells. However, this company uses the harmful substance cadmium, and its public reputation is therefore more vulnerable.

A "green industry" such as photovoltaics would do well to proactively engage with these problems. Only if the industry takes the initiative itself in organising the return and disposal of its products will it be able to avoid the WEEE being extended to PV components as the quantities of materials it uses continue to grow in future.

RoHS directive

PV components are not currently affected by the EU's RoHS directive (restriction of the use of certain hazardous substances). As of 1 July 2006 lead, mercury, cadmium, hexavalent chromium and other substances can basically no longer be used in the manufacture of electrical and electronic equipment. The plan to ban lead in particular presents a challenge to the solar industry. Traditionally solder containing lead has almost always been used to join together the individual PV cells. But lead-free products are already available. *Schott Solar* uses solder made of 96.5% tin and 3.5% silver; the percentage of lead is tiny and complies with RoHS requirements. Crystalline modules produced by *Mitsubishi Electric* have been lead-free since 2003, according to company information. The RoHS directive presents a special challenge for manufacturers of thin-film modules based on cadmium telluride (CdTe). They will need to be granted a special exemption from the RoHS rules.

Sustainability also an issue in the IEA-PVPS

At the 20th European Photovoltaics Conference in Barcelona the IEA-PVPS[9] organised a workshop on the topic of sustainability. Experts from the fields of environmental audit, recycling, product return systems and legislative bodies discussed the status quo. The results of the workshops reveal a common awareness of the issues and the need for further research into this area, as well as improved technical conditions.

[9] www.iea-shc.org

Solar collectors

Overview

As in 2003 and 2004, the second section of our report deals with the active application of solar thermal energy with the help of solar collectors, i.e. generating heat from the sun's thermal radiation. Please refer to our 2003 report for a detailed description of the technologies used. In this year's review we concentrate on a description of European companies, an overview of the market and an update to our forecasts.

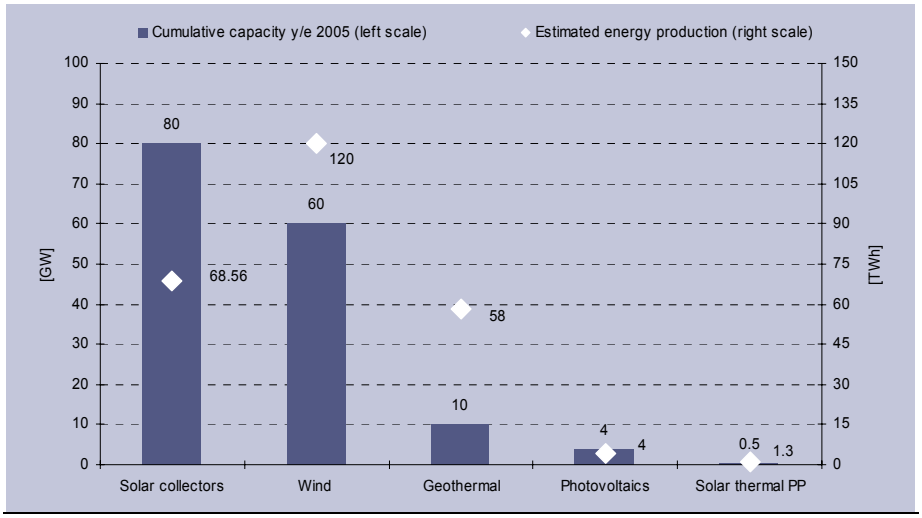
High energy prices fuel demand

Higher oil and gas prices are actually fuelling demand for solar heating systems more strongly than for photovoltaics. On the other hand, many countries do not offer adequate political support for solar thermal power. With photovoltaics, feed-in tariffs for renewable energy provide the necessary investment security, but there is no equivalent legislation in the solar thermal power segment.

Contribution from solar thermal power is underestimated

Compared with other forms of renewable energy, solar heating's contribution towards meeting global energy demand is second only to wind power, and much bigger than photovoltaics' contribution. This fact is often underestimated. The newly defined conversion factor of 0.7 kW_{th} per m^2 of collector area makes it simple to compare the capacities of the different renewable energies currently in use. Fig. 16 shows the projected cumulative capacity ($GW_{e/th}$) at the end of 2005 for wind, geothermal, photovoltaics, solar heating and solar thermal power stations, as well as the energy produced in one year ($TWh_{e/th}$). In its World Energy Assessment based on figures from 1998, the UNDP showed a similar table.[10]

Fig. 16: Cumulative capacity (GW) at y/e 2005 and energy generated (TWh)



Source: Sarasin estimates, 2005

Leading players in solar thermal power

Concentration at the top

The global solar collector industry is very fragmented and has many small players. As far as European companies go, however, certain major players are slowly starting to crystallise. The Austrian company *GreenOneTec,* Europe's biggest producer of flat-plate collectors, has taken over the European number

[10] World Energy Assessment, Energy and the challenge of sustainability, UNDP, 2000, New York

two, the Greek company *Foco*. A third important player is involved in this merger: Denmark's *VKR Holding*, which owns a stake in both companies. Other important companies who want to compete in the premier league include *Schüco*, *Viessmann* and *BBT*. All three have announced or already completed additional expansion plans for their solar business. Fig. 17 provides an overview of the most important European players in the solar heating industry.

Fig. 17: The most important European players in the solar heating industry

Company	Production 2004 (1000 m2 collector area)		Sales 2004 (EUR m)		Employees 2004	
			Total	Solar heating	Total	Solar heating
Alanod-Sunselect (DE)	900	(C)	255	<7%	950	14
Bosch Buderus (DE)	135	(FC/RC)	2'500	<3%	13'000	150
Chromagen (IL)	160	(FC/TS)	28	100%	190	190
Foco (GR)	75	(TS/FC)	-*	100%	90	90
Giordano (F)	70	(A/TS/FC)	30	85%	230	213
GreenOneTec (AT)	310	(FC/A/RC)	28	100%	150	150
Huemer Gruppe (AT)	75	(A/FC/RC)	12	100%	53	53
KBB (DE)	150	(A/FC)	7	100%	28	28
Paradigma/Ritter (DE)	35	(RC/FC)	42	ca. 50%	275	50
Pro Solar (DE)	25	(FC/RC)	11	100%	45	45
Rheem/Solahart (AU)	320	(TS/FC/RC)	400	ca. 15%	430	190
Schott-Rohrglas (DE)	10	(RC)	180	k.A.	1'300	80
Schüco (DE)	60	(FC)	1'300	<4%	4'500	100
Thermomax (UK)	38	(RC)	16	100%	120	120
TiNOX (DE)	320	(C)	5	100%	12	12
Viessmann (DE)	150	(FC/RC)	1'250	<6%	7'000	110
Wagner Solar (DE)	80	(FC/A)	82	ca. 40%	160	100

*FY ended Oct. 04; SH: Solar Heating; FC: Flat-plate Collectors; RC: Tube Collectors; TS: Thermosiphon; A: Absorber; C: Absorber Coating
Source: W.B. Koldehoff, October 2005.

Alanod-Sunselect

At the start of the year *Interpane Solar* was taken over by *Alanod* and the merged group renamed *Alanod-Sunselect*. Last year this company was easily the European market leader in absorber coatings. The company has two manufacturing processes, one based on copper and the other on aluminium.

BoschBuderus (BBT)

The full merger of *Bosch* and *Buderus* is now complete and from now on the solar heating activities will be concentrated in the division *Bosch Buderus Thermotechnology (BBT)*. This business also includes *Junkers*. As of 2006 *Bosch* also plans to buy its collectors from *Solar Diamant* (previously *GreenOneTec*). *BBT* is concentrating increasingly on system integration, specifically on a solar-powered combi unit "Crea-Smart". *BBT* is increasing the manufacturing depth of its supplier *Innovar* in Switzerland, where in future the absorber sheets will be galvanised.

Chromagen

Chromagen is one of Israel's biggest solar heating producers and mainly makes thermosiphon systems. The company is focusing increasingly on higher quality standards and longer service life. Its export quota has risen slightly, particularly to Germany but also to Europe as a whole, as well as to the Middle East and Africa.

Foco

As already mentioned, all of *Foco's* production capacities were taken over by *GreenOneTec* and the most important machines for making absorbers were transferred from Greece to Kärnten in Austria. This completes the merger of Europe's top two manufacturers of flat-plate collectors. The manufacture of col-

lectors will be concentrated in one plant operated by *Solarcap* (see *VKR Holding*) in Denmark, in an attempt to exploit synergy effects and economies of scale.

Giordano Industries

Jacques Giordano Industries has been producing solar heating systems for more than 20 years. *Giordano* not only offers glazed solar collectors, but a solar-powered shower and plastic absorbers for swimming pools. In particular, the company is also active in France's overseas territories.

GreenOneTec

GreenOneTec is a technology leader and easily the biggest producer of solar collectors in Europe. Following the integration of *Foco*'s production facilities, production of roughly 500,000 m^2 is planned for 2006. According to statements from CEO Robert Kanduth, a second phase of capacity expansion to 1 million m^2 is on the cards.

Huemer Group

The *Huemer Group* comprises the companies *Böhm* (absorber production), *Sunmaster* (collector production) and *Xolar* (regional trading and assembly). This up-and-coming company is focused on OEM production, but also develops new connection techniques for absorbers.

KBB

The young company *KBB* has sold its production facilities and know-how in the field of soldering technology and laser welding of absorbers to *Viessmann*, which has traditionally been the biggest customer of *KBB* products. In future *KBB* plans to concentrate not only on absorber production, but increasingly on the manufacture of flat-plate collectors (OEM).

Paradigma/Ritter Solar

Paradigma/Ritter Solar is now the leading provider of evacuated tube collectors (ETC) in Germany. The joint venture with the Chinese company *Linuo* is very successful. *Ritter Solar* now offers an ETC product, the "Aqua-System". Here the hot water flows directly through the ETC and existing storage modules can be included in the system.

Rheem/Solahart

With a collector area of 320 Tm^2, Australia's *Rheem/Solahart* is a globally active company and a leader in the field of hot water systems (gas, electric and solar powered). The market focus is on the southern hemisphere, mainly the sale of thermosiphon systems. The company also makes flat-plate and tube collectors (a recent addition). The acquisition of *Edwards,* Australia's number two in hot water systems, enabled *Rheem/Solahart* to significantly strengthen its position.

Schott Rohrglas

Schott Rohrglas is best known for its collector tubes with high vacuum insulation. *Schott Rohrglas* also makes tubes for parabolic through receivers, a key component in solar thermal power stations. The receiver tube is 4 m long. This makes *Schott* one of the global leaders in the solar industry, and it is the only company to offer components for virtually all the application fields of photovoltaics and solar thermal power.

Schüco

Schüco is working hard to expand its solar heating business, especially in Germany. In mid-August the company announced that the future "theoretical production capacity" of its collector plant in Bielefeld would be 1.5 million m^2. *Schüco* pursues a successful marketing policy and offers integrated solutions (integration of solar heating and PV systems into buildings/façades).

Thermomax

With an output of 38 Tm^2 collector area, the British company *Thermomax* is Europe's biggest producer of evacuated tube collectors (ETC). The company makes substantial investments in quality assurance and process optimisation. It is increasingly developing applications in the field of solar-assisted cooling (SAC). Its quota of exports to non-EU countries is rising.

TiNOX

TiNOX, the original pioneer of the distinctive blue titanium absorber tapes, was taken over by *MAGE Industrie Holding* in the summer of 2003 and is now number two behind *Alanod-Sunselect*. The *MAGE Group* combines several medium-sized industrial companies that are internationally active in the ancillary construction trade, specialising in roof technology, facade technology and fastening technology. Within the Group, *TiNOX* represents the main arm of the renewable energies business.

Viessmann

Having increased its collector area capacity by 30%, *Viessmann* is now joint leader in solar systems in Germany, along with *BBT*. But *Viessmann* is also expanding its plant in Faulquemont (France). In addition to the coating line, a soldering and laser welding facility is planned for next year. This would enable the company to cover the entire production chain. Viessmann also offers PV systems based on flat-plate collectors.

Wagner Solar

Wagner Solar grew from a pioneer to an SME company with a strong innovation drive, including non-reflective solar glass and flat-plate collectors that currently offer the highest energy yield. The company offers Europe's most powerful flat-plate collector using Iso-AR-Glass. *Wagner Solar* is also successful at selling PV modules and (a recent addition) heating systems powered by wood pellets. In 2005 the company expects to achieve more than 100,000 m^2 of collector area and sales in excess of EUR 100 m for the first time. *Wagner Solar* is also expanding in other EU countries and has set up several local offices for this purpose.

VKR Holding

VKR Holding is one of the companies behind the merger between *GreenOneTec* and *Foco*. This Danish holding company, which includes the leading manufacturer of roof windows *Velux*, owned a majority shareholding in *Foco* through its Danish company *Solarcap*, and also has a significant holding in *GreenOneTec*. Last year the combined output of the two OEM manufacturers was a collector area of around 400,000 m^2 (280 MW_{th}). This gives them a European market share of almost 25%.

Principal global markets

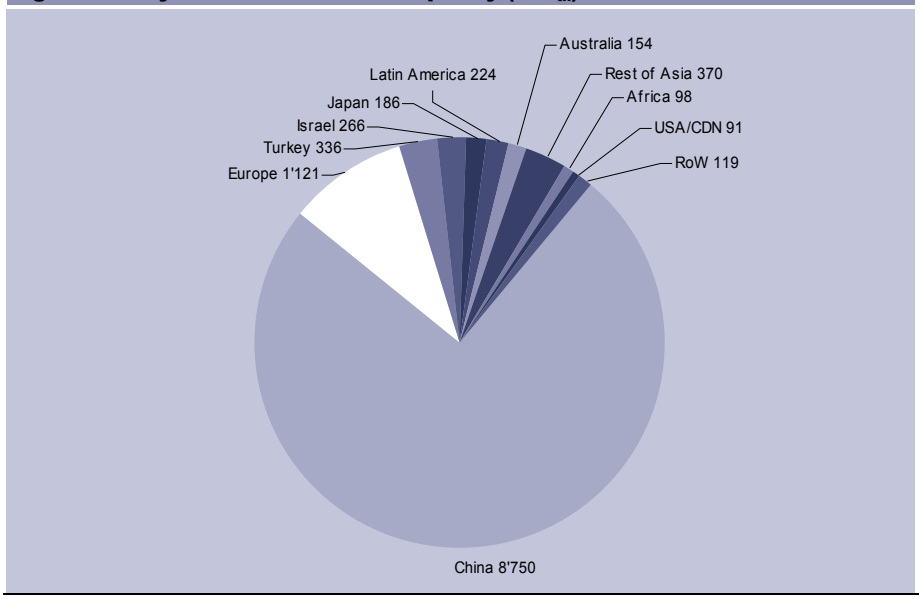
Global growth of 30% in 2004

There are still huge differences between national markets in terms of newly installed collector area. China, easily the world's biggest market, continues to enjoy dynamic expansion and sets the global pace of growth. Newly installed capacity in 2004 came to 11,700 MW_{th}[11] (16.72 million m^2), an increase of roughly 30% on 2003 (see Fig. 18). Around 75% of this capacity was installed in China. Apart from China, other important markets include Germany, Greece, Austria and also Turkey, Israel and Japan. The biggest markets for solar collectors are

[11] In this report the installed solar collector capacity is no longer expressed in square metres, but for the sake of consistency in kilowatts of thermal energy based on the new conversion factor of 0.7 kW_{th}/m^2. For more details, visit www.iea-shc.org

therefore located in Asia and Europe, even though other regions would be more advantageous as they enjoy more sunshine.

Fig. 18: newly installed collector capacity (MW_{th}) in 2004



Underlying data: W.B. Koldehoff, October 2005

Top ten solar collector countries: China and Australia overtake Germany

China's dominance in newly installed area is mainly due to the huge size of its population. But even in pro capita terms, China's capacity of 6.7 kW_{th} per 1,000 inhabitants now puts it in fifth place, which means it has overtaken the stagnating German market (6.4 kW_{th}/1,000 inhabitants) during the last year. Since 2000 China's pro capita installation has risen by 20% p.a. and still shows no sign of slowing (see Fig. 18). Israel is still undisputed leader when measured by "newly installed capacity per 1,000 inhabitants". Last year Israel managed to put a stop to the downturn it has suffered since 2001, and capacity rose again by 7%. Austria and Greece (second and third place) also increased their capacity again in 2004, by 10% and 28% respectively. Turkey, Switzerland and Denmark all posted moderate growth. Spain has broken into the Top Ten for the first time, pushing out Japan by a whisker.

Australia expanding, but 2004 was a difficult year

Australia was unable to repeat its stunning 2003 performance of +136%, but still managed to grow well over 30%. It was a difficult year for Australia in relative terms. The 2003 boom was obviously fuelled by the *Renewable Energy (Electricity) Act 2000*, which came into effect in April 2001[12]. The rebate for installing a solar hot water system has since been cut from AUD 1,100 to 700. We therefore do not anticipate overly dynamic growth for the current year either. Next year new orders are anticipated from the State of Victoria, which passed a new building ordinance effective 1 July 2005. This stipulates that solar energy must ultimately cover 60% of hot water generation. With one stroke, this has created a potential market of some 30,000 systems.

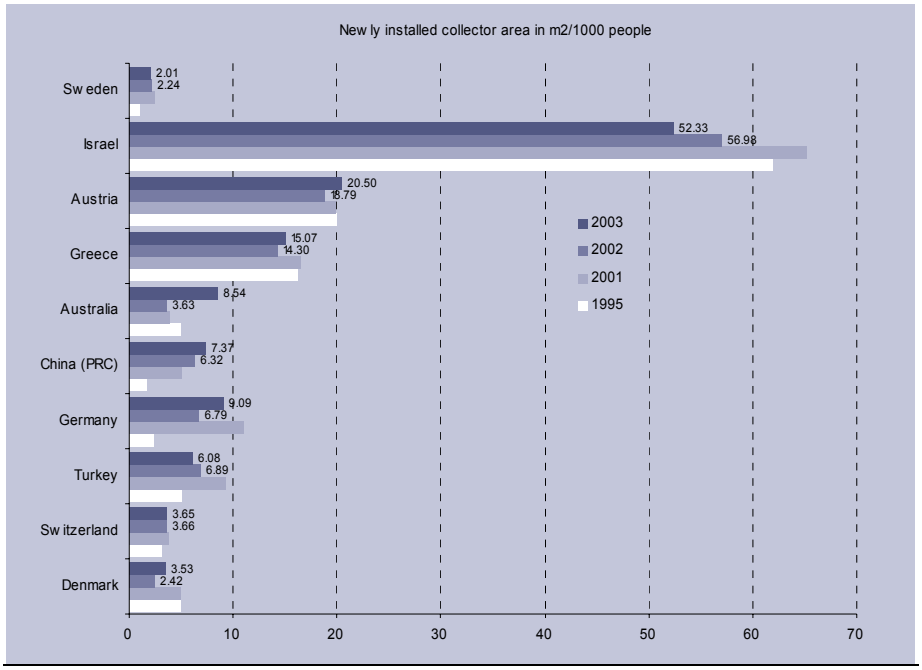
Enormous potential for solar heating

The example of Australia shows how sensitively a young market can react to changes or uncertainties in state subsidy programmes. The cost of purchasing

[12] www.greenhouse.gov.au/markets/mret/index.html

heating systems powered by solar collectors is higher than for a conventional heating system. A sensible programme of subsidies, combined with rising or high fossil fuel prices, can open up enormous potential here. Unlike photovoltaics, solar heating directly replaces valuable gas, oil or electricity that is used for heating or cooling purposes. This would allow Europe to replace around 30% of its oil imports form the Middle East, for example.

Fig. 19: Top ten countries – Market size per head of population: Annual newly installed collector capacity in kW_{th} per 1,000 inhabitants

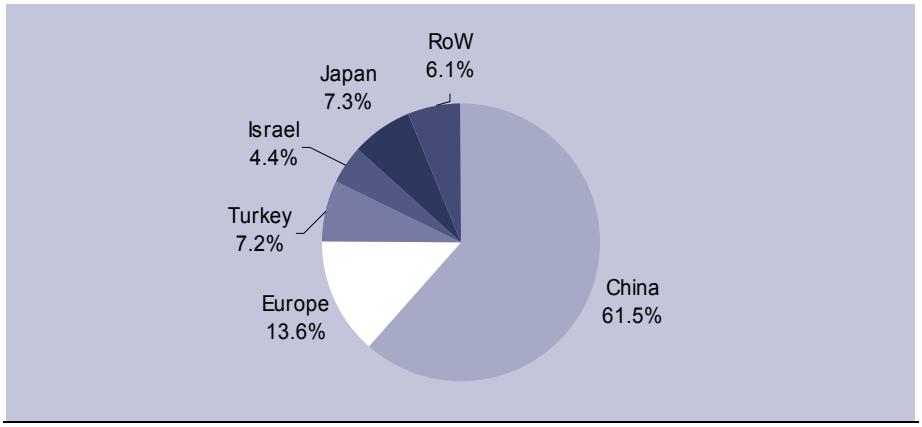


Underlying data: W.B. Koldehoff, October 2005

Cumulative collector capacity rose 19% worldwide

Fig. 20 illustrates the collector capacity currently in service in the individual countries and regions at the end of 2004. Compared with 2003, this capacity has grown 19% to a total of 73 GW_{th}. The geographical spread has stayed relatively stable. China is also in top place in terms of the amount of solar collector capacity actually in service, with a share of 62% compared with 59% last year.

Fig. 20: Total global solar heating systems in service at y/e 2004. Total capacity = 73 GW_{th}



Underlying data: W.B. Koldehoff, October 2005

China

China: biggest market still growing

China is the world's biggest market for solar heating, with a share of almost 75% of the total collector capacity installed worldwide in 2004. This is equivalent to a newly installed capacity of 8,750 MW_{th}, a percentage increase of roughly 31.5%. The cumulative capacity at y/e 2004 was around 44,900 MW_{th}. 90% of systems are installed to heat water in private households, 10% in hospitals, schools, hotels, etc. About 85% are flat-panel collectors with thermosiphon systems and 15% evacuated tube collectors. There is a trend towards higher quality flat-panel collectors with longer service life, especially for large showpiece projects. More and more of these high-quality collectors will also be destined for export. To this end China is increasingly looking to enter collaborations with western/European institutions in the areas of quality and standardisation. A number of providers of evacuated tube collectors are already outsourcing manufacture of their glass tubes to China. Growth in China does not benefit from government subsidisation programmes for installing the systems. Funding is only provided for research and development. But volume growth is expected to remain high for the coming years, because rural and suburban regions are likely to experience increasing energy shortages with booming industry taking up more and more of the limited energy supply. The government's target is for a cumulative collector capacity of 100 MW_{th} in 2010, and 190 MW_{th} in 2020.

Japan

Japanese market in crisis

Last year around 186 MW_{th} of new collector capacity was installed in Japan. This represents an increase in newly installed capacity of just 1% compared with 2003. At year-end 2004 a total of around 5,330 MW_{th} of collector capacity was in service. The Japanese market has been more or less stagnating since 1998. Up to the end of 2005 the government provides a subsidy of around EUR 100-140 EUR/m^2 for a collector with a closed-loop system (no thermosiphon). This represents about 10% of the investment costs. Subsidies will stop next year, because the government thinks that the collector market is big enough and stable enough to stand on its own feet. But this could tip the Japanese market into crisis. Furthermore, the products are not state of the art and some of them are aesthetically unappealing. Consumers see solar collectors as being rather outdated. The government target of 25 GW_{th} cumulative collector capacity in 2010 is unlikely to be reached without additional supportive measures. This would require annual growth of 25% in the years to come. Our forecasts of newly installed capacity for the Japanese market are 192 MW_{th} for 2005 and 198 MW_{th} for 2006.

Turkey

Closed Turkish market is opening up

Last year the Turkish market expanded by 3%, or 336 MW_{th}. Per capita installation was 4.7 kW_{th} per 1,000 inhabitants in 2004, placing Turkey seventh in the world rankings. People can afford solar collectors without government subsidies. It is quite simply the cheapest way to provide hot water. Because domestic demand is so high, a strong Turkish solar industry has developed. Over the years the quality of the systems has improved significantly, in particular in a drive to increase exports to Western Europe. Like Israel, Turkey was a relatively closed market for a long time, with its own product standards and own philosophy. There are now joint ventures between EU companies and Turkish firms to boost

sales of highly efficient solar collectors in the top price segment.[13] These products are particular attractive to the Turkish tourist industry.

USA

Rising oil & gas prices, and a new Energy Bill

In the USA, solar collectors (mainly unglazed black tube systems) have been used exclusively to heat swimming pools. But now soaring oil and gas prices are kindling interest in combined hot water and heating systems powered by solar energy. This considerably shortens the payback period. In addition, many federal states have created incentive programmes for solar systems (both PV and solar heating). The recently passed national Energy Bill proposes tax credits for the installation of solar systems and explicitly includes solar heating systems as well. Our forecasts of newly installed capacity for the US market are 120 MW_{th} for 2005 and 157 MW_{th} for 2006.

Market trends in Europe

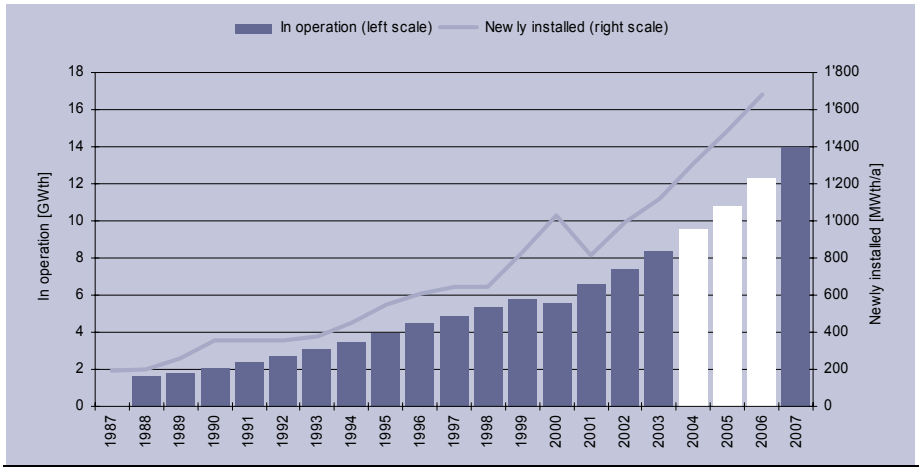
2001 records beaten

In 2004 Europe's solar heating market more than made up the ground it lost in the past two years, and the 1,130 MW_{th} newly installed solar collector capacity was more than in the record year of 2001 (1,030 MW_{th}). This was despite uncertainties about subsidisation conditions in the most important market, Germany, and increasing competition from photovoltaics in private household installations.

13% growth in installed solar collector capacity in 2004

According to figures published by ESTIF[14] in June 2005 for Europe[15], newly installed collector capacity in 2004 rose 13% to 1,120 MW_{th} (1.60 million m^2). This year we predict 17% growth to 1,311 MW_{th}. We expect growth to average 13% in both the coming years (see Fig. 21).

Fig. 21: Trends for solar collectors in Europe (EU 25, CH and Norway). Sarasin estimates for 2005 to 2007: 1311, 1488 and 1687 MW_{th}



Source: ESTIF, June 2005; W.B. Koldehoff, October 2005 and own estimates

75% of collectors installed in Germany, Greece and Austria

In Europe, sales of solar collectors are still concentrated in three countries: Germany, Greece and Austria (see Fig. 22). 75% of new capacity is installed in these nations. As far as the other countries are concerned, the main trends were

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[13] Turkey Special, pages 42 – 50, Sun & Wind Energy 2/2005

[14] ESTIF: European Solar Thermal Industry Federation, www.estif.org; Trends and Market Statistics 2004, June 2005

[15] EU 25 incl. Switzerland and Norway, excl. Luxembourg

higher than average growth rates in Italy, Spain and France, as well in the UK, Belgium and Ireland – although the last three started from a very low base. The 10 new EU member states had a combined total of 6% of the solar collectors in service. These markets are not listed separately yet, because the data sources still need to be harmonised.

Fig. 22: Solar heating market in Europe 2004: Overview listed by market share, with capacity now in MW_{th}

Country	2004 in service (MW_{th})	Europe market share (%)	Market growth 2003-2004 Installed 2003	Installed 2004	Market growth	2005 market forecast Total	2006 market forecast Total
Germany	3'923	40%	504	525	4.2%	637	700
Greece	1'979	20%	113	151	34%	119	126
Austria	1'460	15%	116	128	11%	140	151
Italy	311	3%	35	43	22%	52	56
Spain	294	3%	49	65	33%	98	140
Switzerland	247	3%	19	22	16%	27	28
Denmark	221	2%	13	14	5%	17	18
Netherlands	198	2%	19	20	1%	21	23
France (EU)	192	2%	27	39	41%	67	84
Sweden	130	1%	13	14	11%	18	20
UK	118	1%	15	20	32%	25	28
Portugal	101	1%	4	6	50%	8	9
Belgium	34	0.3%	8	10	34%	13	15
Norway	13	0.1%	2.1	2.1	0%	3	3
Finland	8	0.1%	1.4	1.4	0%	1	1
Ireland	5	0.1%	0.4	1.4	233%	2	2
New EU-10	542	6%	52	60	15%	64	83
Total	**9'776**	**100%**	**991**	**1'121**	**13%**	**1'311**	**1'488**

Underlying data: ESTIF, June 2005; W.B. Koldehoff, October 2005 and own estimates

Germany

German market grew 4% in 2004

After a poor year in 2002, sales of solar collectors rose an impressive 33% in 2003. But they are expected to have fallen back sharply in 2004, although growth of 4% is still likely. Germany is Europe's biggest market (40%), with approximately 4,000 MW_{th} cumulative capacity currently in service.

Market incentives provide valuable support

Solar heating systems receive substantial support in Germany through the market incentive programme (MIP). As of 1 July 2005, the MIP[16] grants differentiated subsidies for solar collector systems. The level of subsidy for systems used to heat greywater is EUR 105 /m^2 of gross collector area, and for combi systems (hot water and support for space heating) as high as EUR 135/m^2. To qualify for a state subsidy, the collectors must now produce a minimum yield of 525 kWh/m^2 (750 kWh/kW) and also meet the criteria of the ecolabel Blue Angel (RAL UZ 73), status 2004[17]. A current overview of the subsidy programmes provided by the government and individual federal states is available from BSi.[18]

21% growth predicted for 2005

In the first eight months of 2005 there was a 75% increase in the number of MIP applications compared with last year. The inflow of new applications continues to be high thanks to the sunny autumn and persistently high prices for fossil fuels.

[16] Marktanreizprogramm für erneuerbare Energien des Bundesamtes für Wirtschaft und Ausfuhrkontrolle (BaFa), www.bafa.de

[17] www.blauer-engel.de

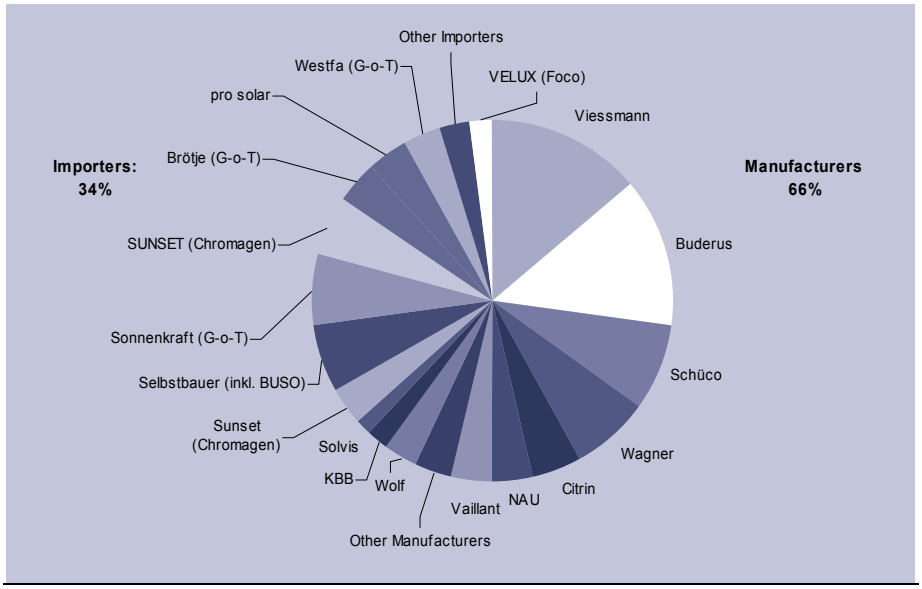
[18] www.bsi-solar.de/foerderprogramme.asp

The market received an additional boost from the change in the incentive rules as of 1 July, which gave lower subsidies for small systems but higher subsidies for space heating systems. We predict full-year growth of 21% in newly installed systems. Our forecasts of newly installed capacity for the German market are 637 MW_{th} for 2005 and 700 MW_{th} for 2006. The government target of 7 GW_{th} cumulative solar collector capacity by 2006 will probably not be achieved. We predict around 5.26 GW_{th}.

In recent years there have been big fluctuations in the entire solar collector market in Germany. The market shares of individual players have oscillated wildly as well. The position of the two leaders, *Buderus* and *Viessmann*, has been fairly constant and uncontested. Wagner came third in 2003. Winners in recent years include *Sonnenkraft*, *Wolf* and *Schüco* (see Fig. 23).

Cost reductions have also been made in recent years following more industrialised manufacturing and economies of scale in marketing and distribution. Increasing concentration is also apparent in production, while at the same time distribution is now extending more over to providers of traditional heating boilers.

Fig. 23: Market shares of manufacturers and providers of flat-plate collectors in Germany in 2004 (total 480 m^2 MW_{th}, or 91% of total market).



Underlying data: W.B. Koldehoff, October 2005. OEMs in brackets (G-o-T: GreenOneTec)

Difficult situation in solar heating

In Germany the attractive payments for solar energy fed into the mains grid seem to have made solar heating slightly less popular with owner occupiers. But high oil and gas prices are helping to reverse this trend. According to a survey of 1,700 plumbing and heating installation firms conducted by Europressedienst[19], most customers cite cost savings as the main motive for purchasing a solar heating system. The Regenerative Heat Act (*Regeneratives-Wärme-Gesetz,* RegWG), which the industry hopes will be introduced soon, would provide additional support. By imposing a carbon tax on the use of conventional forms of energy such as oil and gas, this law aims to provide a financial incentive for producing heat from renewable sources. But the government is also considering an

[19] Perspektiven der Solarthermie in Deutschland 2005/06, Europressedienst EuPD, Bonn, July 2005

ordinance that makes the use of solar-powered heating systems compulsory when building new single- or multi-occupancy dwellings, or imposes an obligation to use such systems. But it will be at least a couple of years before such regulations provide new stimulus to Germany's solar heating market. As far as climate protection is concerned, solar heating definitely deserves more support, since specialist publications show that when in service a solar collector saves well over twice as much CO_2 (relative to area) than a comparable PV system.

Greece

Saturation point reached?

Last year many existing solar heating systems were replaced, resulting in 151 MW_{th} of newly installed capacity. This is equivalent to 34% growth on last year. Greece therefore took Austria's place as number two in new installations. The cumulative capacity of 180 kW_{th} per 1,000 inhabitants is already the second highest after Israel, so a certain amount of saturation is likely. Additional stimulus could come from the wider promotion of systems for solar-assisted cooling. Our forecasts of newly installed capacity for the Greek market are 119 MW_{th} for 2005 and 126 MW_{th} for 2006.

Austria

Austria becomes the biggest exporter of solar collectors

The positive market growth that Austria has enjoyed since 2000 continued in 2004. Last year glazed collectors with a capacity of approximately 350 MW_{th} were produced in Austria (2003 production: 285 MW_{th}). In 2004 around 65% or collectors produced were exported, compared to 59% in 2003[20]. Austria's *GreenOneTec* is Europe's biggest producer of flat-plate collectors. The company operates around two-thirds of Austria's entire production capacity. The domestic market volume for glazed collectors was 128 MW_{th} (117 MW_{th} in 2003), which is 9.4% higher than last year. Cumulative capacity of 1,460 MW_{th} was in service at y/e 2004. Subsidies vary from one federal state to another. They average around EUR 4,900 for a solar system providing heating support (20 m^2 collector area, 1,500 l storage tank).

Market forecast for Austria up to 2010

Austria's solar heating market posted average annual growth of 15% during the period 1990-2000. If additional market impulses managed to fuel this growth up to 2010, Austria would have almost 2,800 MW_{th} collector capacity installed in this Kyoto target year. Total sales in the solar heating industry would rise to EUR 318 m per year (2004: EUR 178 m). The CO_2 reduction achievable every year would therefore be almost one million tonnes. Our forecasts of newly installed capacity for the Austrian market are 140 MW_{th} for 2005 and 151 MW_{th} for 2006.

Switzerland

Solar heating market: Trend reversal confirmed

Last year a total of 21.8 MW_{th} new capacity was installed in Switzerland.[21] This is equivalent to 16% growth on last year. The installation rate has therefore increased for the second consecutive year. The lion's share (96%) was flat-plate collectors. Previous sales figures were only higher in 1998 (22.2 MW_{th}). High energy prices, coupled with the campaign to promote solar energy launched two years ago, seem to be making an impact and confirm the trend reversal

[20] Solarmarkt in Österreich 2004, Austria Solar, www.austriasolar.at

[21] Solar - Schweiz. Fachverband für Sonnenenergie, market survey 2004; www.solarpro.ch

observed last year. Our forecasts of newly installed capacity for the Swiss market are 27 MW_{th} for 2005 and 28 MW_{th} for 2006.

Other markets

Two rising stars: France...

The French collector market has seen very dynamic expansion over the last four years, with growth rates of more than 40%. The state subsidisation programme "Plan Soleil" has provided an important stimulus and ensured that around 36 MW_{th} new capacity was installed in 2004. Since January 2005 up to 40% of the purchase cost of solar heating systems can be offset against income tax. This figure will even increase to 50% as of 2006. The potential is still massive, because the per capita collector area in France is still very low. Our forecasts of newly installed capacity for the French market are 67 MW_{th} for 2005 and 84 MW_{th} for 2006.

... and Spain

Spain is another market where expectations have been high for some time. Now it finally seems to meeting these expectations, notching up growth of 33% to 65 MW_{th} last year. We still have high hopes, as almost 30 cities and local authorities have since passed building ordinances that make it compulsory to install solar heating systems when building or renovating properties ("Barcelona model"). This commitment to solar power is due to be extended across the entire country. Our forecasts of newly installed capacity for the Spanish market are 98 MW_{th} for 2005 and 140 MW_{th} for 2006.

Global market trends up to 2020

China growing steadily

For several years now China has shown itself to be a dynamic and self-sufficient market with annual growth rates of over 20%. Demand for solar collectors will continue to rise in future because the Chinese economy is booming. Taking into consideration the government's renewable energy projects mentioned earlier and soaring fossil fuel prices, we think this current trend is set to continue.

New markets will emerge

We can expect to see new markets emerge in countries that enjoy a lot of sunshine. These include southern European countries, the USA and Australia, as well as newly industrialised countries such as India, Indonesia, Mexico and Brazil.

EU well short of its targets

In its White Book, the European Commission has set a 2010 target of 70 GW_{th} for solar collectors in service. Despite the respectable growth rate of 13% in the period 2003-2004, however, only 9.8 GW_{th} capacity was in service at the end of last year. Given the current growth rates, we estimate that the EU target will not be reached until 2020 at the earliest.

Growth in Europe of at least 13% up to 2010

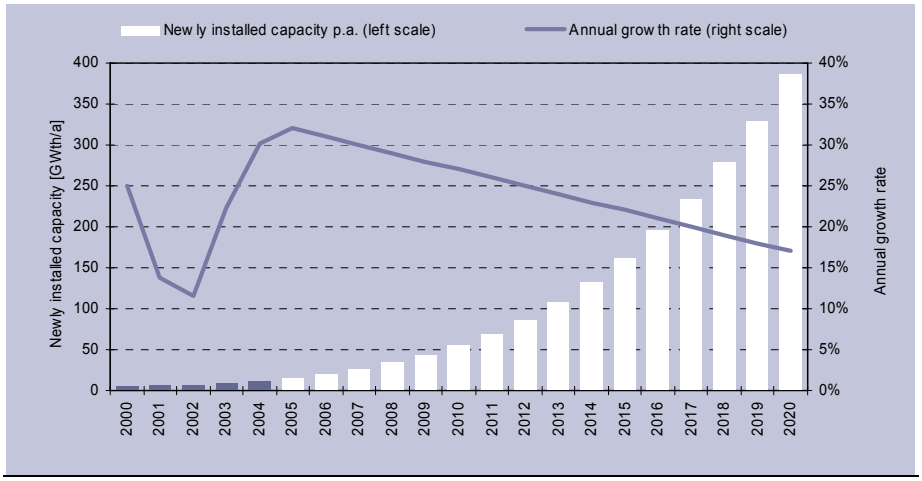
After collapsing in 2002 (-22%), the European market has quickly recovered and reverted to 13% growth in 2003/04. Taking a conservative view, the market should also be able to maintain this rate of growth up to 2010. If, however, new legislative or political measures provide additional support in different countries, and gas & oil remain expensive, growth rates could well be much higher.

Heating and cooling with renewable energies

Heating energy accounts for roughly 50% of total EU energy consumption by end users. This magnitude is unfortunately totally out of proportion to the public and political attention devoted to heating energy. To provide stronger support to solar heating in the important energy segment of "heating and cooling", there

need to be more effective public subsidisation programmes or legal measures, such as the previously mentioned “Barcelona model” in Spain or the planned “Regenerative Heat Act” in Germany. The European industry association ESTIF, together with the European Renewable Energy Council (EREC)[22] and other organisations, has published a declaration calling for an EU directive to ensure that renewable energies (solar thermal power, biomass and geothermal energy) will cover roughly 20% of heating and cooling energy by 2020.

Fig. 24: Sarasin forecast for the global solar collector market. Newly installed collector capacity in GW_{th} per year



Source: Sarasin, 2005

Global growth of 25-30% up to 2010

In 2004 the world’s newly installed collector capacity was 11.7 GW_{th}, roughly 30% higher than in 2003. For the current year 2005 we predict that newly installed collector capacity worldwide will reach around 15.5 GW_{th}, which is 32% more than last year. This growth will come mainly from the boom in China, but also from other non-European countries. The global growth rate is likely to remain between 25% and 30% up to 2010. In 2010 we therefore predict a market volume (newly installed collector capacity) of 55 GW_{th}, with roughly 250 GW_{th} on stream worldwide. As the market starts to become saturated, we expect average growth will then ease back in the following decade (2011- 2020) to around 20% p.a. The global market for newly installed solar collectors would therefore reach a volume of approximately 390 GW_{th} in 2020 (see Fig. 24).

Solar-assisted cooling

Conventional AC systems can cause power cuts

Solar-assisted cooling (SAC) is becoming increasingly important worldwide, not least because of global warming. Demand for air conditioning is also booming as standards of personal comfort rise. In cities such as Houston, Sydney, Madrid and Rome, for example, almost all the buildings are now fully air-conditioned. Even in Germany around half the large office buildings already have air conditioning, with a steep upward trend. In some countries this surge in demand is increasingly causing network overload and failure of the mains grid on hot summer days. Solar-assisted cooling therefore has enormous potential for saving electricity worldwide. Air conditioning is also a huge market in commercial terms. The

[22] Joint Declaration for a European Directive to promote renewable heating and cooling; European Renewable Energy Council (EREC), Brussels, April 2005; www.erec-renewables.org

industry's turnover was around USD 50 billion in 2003, with 10% of sales generated in Europe. Conventional air conditioning units that use compressors consume a lot of electricity, most of it during peak load times.[23]

Market of the future: solar cooling

Something that is common in other areas – using thermal energy to generate cold – is a very promising option for solar thermal power as well: Traditional air conditioners and refrigerators use electrical compressors whose energy consumption rises disproportionately when the ambient air temperature is higher. The novel idea behind SAC is to use what actually causes the high temperatures – namely the sun itself – to power the cooling units. Demand for cool air rises and falls almost in synchronisation with the supply of solar energy. Compared with traditional AC units, efficient solar-powered systems can reduce the electricity costs for a building's air conditioning by at least 40-70%. Furthermore, the solar power can be used all year round for heating water, and on cold days as a support for the main heating system.

At the moment Europe has around 40 systems (25 of them in Germany) in service for solar-powered air conditioning of buildings, with a combined collector area of approx. 17,000 m^2 and a total capacity of 4.4 MW_{th}. SAC is a very promising solar application in buildings and is attracting increasing interest from private customers, hotel owners and industry. Now the market needs more companies that can offer integrated solutions for heating and cooling residential or commercial premises.

[23] Klimatisieren mit Sonne und Wärme; Dr. Hans-Martin Henning. BINE, themen-infos 1/04; www.bine.info

Solar thermal power stations

Fields of application

Concentrating Solar Power (CSP)

A solar thermal power station usually generates electricity with the use of steam turbines. The steam is produced with the help of solar energy. The "conventional" part of the power station (steam circulation, steam turbine and generator) is not very different from traditional power stations that work with coal, oil or gas. The basic principle of solar steam generation involves concentrating the solar power with a system of mirrors. This is referred to as *Concentrating Solar Power* (CSP).

Solar power stations combined with conventional plants or with a storage system

Solar thermal power stations are usually designed to generate electricity and are therefore mostly large installations with an output of 30 - 200 MW, working at high temperatures (400-800°C). At the moment these systems are the only solar technology capable of replacing comparably sized traditional power stations powered by fossil or nuclear fuels. Apart from 'pure' solar systems, hybrid systems are also planned that are integrated in conventional power stations (e.g. gas and steam) and are responsible for generating some of the steam during daylight hours, thereby saving on fossil fuels. Besides this, more and more systems are being fitted with a heat storage system (e.g. phase-changing media such as molten salts), in order to tailor electricity production more effectively to demand. This allows expensive peak load power to be generated as well. These systems can achieve peak efficiency rates of over 20% when converting solar irradiation into net current fed into the mains grid – not just at selected times, but throughout the day.

Decentralised generation of electricity and heat

Apart from centralised generation of electricity, smaller decentralised power plants based on parabolic trough technology can be used to generate electricity or industrial process heat (for example, to replace diesel generators). Please refer to our 2003 report for a detailed description of the technology. In what follows we limit our comments to a progress report on the various projects.

Existing plants and planned projects

First commercial CSP systems installed in the 80s in California and Spain

Since the early eighties, a number of pilot and demonstration plants have been erected and operated, mainly in the USA and Spain. This was within the framework of the development programme of the US Department of Energy (*SunLab* research facility) and the joint German-Spanish test centre, *Plataforma Solar de Almeria*. Nine SEGS power plants, financed purely with private money and built around parabolic trough technology, were constructed between 1984 and 1991 in the Mojave desert in California with an investment volume of USD 1.2 billion and a total capacity of 350 MW_{el}. They are still operated on a purely commercial basis to this date.

New power station projects progressing slowly

In the last two to three years plans have multiplied for new power generation projects in response to technological advances and also more attractive political and economic conditions, including climate protection agreements, soaring oil and gas prices, subsidy programmes for renewable energies and generous fixed-rate payments for solar energy supplied to the mains grid. However, such large-scale

projects involve protracted procedures to obtain planning permission and secure the necessary funding. One year on, there is therefore little news to report on the project implementation front.

Solar Millennium floats on the stock exchange

On 27 July 2005 trading started in shares of the German project development company *Solar Millennium AG*. The company is confident that it will manage, in collaboration with various partners, to implement a series of projects in the months ahead, especially the parabolic trough projects Andasol 1-3 (Fig. 25, project no. 12) in southern Spain. In accordance with Spain's programme of subsidies, the solar power station will receive EUR 0.18 on top of the normal electricity price as a payment for renewable energy fed into the mains grid.

"Solar tower" being built in Spain

A 100 m "solar tower" is due to be built near the Spanish city of Seville. A subsidiary of the listed Spanish environmental technology group *Abengoa*, the company *Solucar Energia*, wants to build this plant with a capacity of 11 MW under the project name "PS10" (Fig. 25, project no. 13). This project thus involves the commercialisation of a technology in the field of solar energy that has for the most part been shunned in the USA. The tower has 75,000 m^2 of mirrors attached to it via computer-controlled mounts which concentrate the sunlight at the top of the tower and generate steam to power a turbine that provides the electricity. The listed company *Telvent GIT*, headquartered in Madrid, supplies the control system for the moving mirrors, or heliostats.

Iberdrola planning new solar power stations

The Spanish energy group *Iberdrola* plans to build nine solar thermal power stations in the south and south east of Spain (project no. 16). The parabolic trough power stations should each have a capacity of 50 MW. *Iberdrola* is already Europe's biggest producer of wind power, with a total capacity of 3,000 MW. But the Spanish also have conventional power stations fuelled by gas, coal and nuclear energy. *Iberdrola's* announcement was made against a backdrop of new government targets for expanding renewable energy in Spain which were passed at the end of August. These set a target of 500 MW for national solar power station capacity by 2010.

Boost for solar termal power projects in the USA?

The new Energy Bill has at least improved conditions for large-scale solar thermal power projects in the USA. One of the world's biggest solar thermal power stations is due to be constructed in California (project no. 19). *Stirling Energy Systems* from Arizona wants to erect and operate a solar thermal power station near San Diego that will initially provide the local utility company, *San Diego Gas & Electric (SDG&E)* with 300 MW of electricity. The plan is to increase this capacity to 900 MW by 2015. *SDG&E* is committed to increasing its quota of green electricity to 20% by 2010. The "Renewable Portfolio Standard" obliges US electricity providers to generate and sell a specific (and increasing) proportion of their electricity from renewable energy sources.

Fig. 25: Overview of current projects in the field of solar thermal power plants

	Location	Financing	Solar technology	Engineering, supplier	Hybrid operation	Solar capacity (MWel)	Total capacity (MWel)	Project status [a]	due to come on stream
1	Algeria	Algerian Renewable Energy Act / loan following RfP	parabolic trough	Bid Selection	Gas & steam plant	25	150	2	2007
2	Australia	Partly from Australian Greenhouse Gas subsidy	Updraught	SBP/EnviroMission	No	200	200	2	n/a
3	Egypt	GEF/World Bank	parabolic trough	Selection after pre-qualification, RfP & bid selection	Gas & steam plant	30	135	2	2007
4	India	MNES, GEF, KfW	parabolic trough	Fichtner Solar (Consultant to Indian EVU and KfW)	Gas & steam plant	35	120-160	2	2007
5	Iran	Depending on project structure, to be decided / IPDO	parabolic trough	Fichtner Solar and Flabeg Solar (Consultants to IPDO)	Gas & steam plant	70	300-400	3	n/a
6	Israel	Israeli technology programme + banks	parabolic trough	Solel as promoter / selection process not yet agreed	Yes, but high solar quota	100	100	3	n/a
7	Italy	Italian research programme	Parabolic trough (with molten salts)	ENEA (state research centre), industry and Enel	Gas & steam plant	40	500	2	2006
8	Jordan	Depending on project structure, to be decided	parabolic trough	Feasibility study by Solar Millennium; RfP & Bid Selection	Steam or gas & steam plant	30-130	130	3	n/a
9	Crete	Greek Ren.Energy Act & renewable energy finance programmes	parabolic trough	THESEUS A.E. (Solar Millennium, OADYK, Fichtner)	No.	50	50	2-3	2007
10	Morocco	GEF/WB/O.N.E.	parabolic trough	F/S by Pilkington Soar & INITEC; RfP & Bid Selection	Gas & steam plant	30	220	2	2007
11	Mexico	GEF/WB/CFE	parabolic trough	F/S by Spencer Management; Bid under way since 2002	Gas & steam plant	30	300	2	2007+
12	Spain, AndaSol 1-3	Spanish Ren. Energy Act + project financing	parabolic trough	Solar Millennium + ACS Cobra	Yes, with approx. 90% solar quota	3 x 50	3 x 50	1	1st plant: 2006
13	Spain, PS10	Spanish Ren. Energy Act + project financing	Tower	Inabensa/Solucar/Abengoa	Yes, with approx. 90% solar quota	11	11	1	2005/6
14	Spain, Solar Tres	Spanish Ren. Energy Act + project financing	Tower	SENER / Solar Tres	Yes, with approx. 90% solar quota	15	15	3	n/a
15	Spain, Euro SEGS	Spanish Ren. Energy Act + project financing	parabolic trough	EHN / Solargenix	Yes, with approx. 90% solar quota	15	15	3	n/a
16	Spain	Spanish Ren. Energy Act + project financing	parabolic trough	Iberdrola	Yes, with approx. 90% solar quota	9 x 50	9 x 50	3-4	n/a
17	South Africa	Unknown	Tower	ESKOM	No	100	100	3	n/a
18	USA, Nevada	PPA with Nevada Power / project financing	parabolic trough	Solargenix/Schott Solar	Yes, with addition of 25% fossil fuel	64	64	1	2007
19	USA, San Diego	PPA with San Diego Gas & Electric	parabolic trough	Stirling Energy Systems	No.	300	300	2	2007

a) Project status: 1 = under construction; 2 = projects in planning phase; 3 = projects in pre-planning (feasibility study under way); 4 = intended projects
Source: SolarPaces, September 2005 and Sarasin

Second US project using German technology

Another project with a parabolic trough is being constructed in Boulder City in the state of Nevada (project no. 18). Germany's *Schott Solar GmbH* is supplying the solar receivers for the project. These are one of the key components for parabolic trough power stations. The 64 MW power station is due to come on stream in June 2007 and generate electricity for 40,000 homes. The project partner is the US company *Solargenix*. This will be the first commercially operated solar thermal power station to be built in the US for 15 years. The implementation of this project in Nevada will be an initial trigger for the further expansion of this technology.

High development costs hold back the boom

The high development costs for solar thermal power stations are the main obstacle to the technology experiencing a boom. Solar Millennium, for example, had to spend EUR 20 m on bringing the technology for the two Spanish power plants to market and developing the projects. The entire investment cost for realising the three solar thermal powers stations each with a capacity of 50 MW in Andalucia is in the region of EUR 500 m.

Market outlook

Commercialisation – 2006 will be the "year of truth"

Fig. 25 provides an overview of the status of the global projects. 2006 may well turn out to be the "year of truth" for some projects and for the technology's commercialisation. Overall we think the opportunities for this solar technology are very good. At the same time, however, there are substantial risks that could obstruct or delay the use of this technology.

Opportunities

Solar thermal plant technologies offer enormous potential because they depend on intense sunlight and are primarily suited to countries in the sun belt, such as the southern states of the USA, Mexico, southern Europe, Africa, Middle and Far East, India and Australia. The following conclusions can be drawn from the technical progress achieved and the improved overall conditions:

- The cost efficiency of these technologies, i.e. comparable costs to conventional power station technology, looks as if it will become more acceptable in the near future.
- Unlike photovoltaics, this technology is suitable for large power stations that can be extensively used for central power supply and in the long term could even be a substitute for power stations using nuclear and fossil fuels.
- The subsidy programmes and incentives in Spain and the USA especially are a general expression of a stronger emphasis in national energy policies on promoting renewable technologies. In this context centralised solar thermal power is now being "rediscovered".

Threats

There are also certain risks associated with the further development of solar thermal power plant technologies:

- Continuity of the finance terms and subsidy programmes
- Country risks (projects are often located in countries where the overall conditions are uncertain)

- The future of solar thermal power plant technologies depends – far more than in the case of photovoltaics and solar collectors – on their ability to compete on the level of cost. It therefore depends on whether the cost savings projected for the new generation of power plants can effectively be realised.

Industry association says the technology is ready

According to a study by Greenpeace[24] and the European Association of the Solar Thermal Power Industry ESTIA, more electricity could be generated worldwide by solar thermal power stations in 2040 than is currently generated by nuclear and hydroelectric power stations. By 2040 five percent of electricity consumed worldwide could come from solar thermal power stations – despite the fact that electricity consumption is expected to double by then. The study gives practical advice on what needs to be done to ensure the technology becomes established. The Middle East and North Africa could assume a pioneering role. Up to 100 million people living in the sunniest areas on earth could make use of this clean energy source.

Conclusion: Prospects are still intact

As we explained in last year's report, the future of solar thermal power plant technologies is heavily dependent on the success of projects currently in the planning stage. Progress has not been as swift as expected. At the moment the entire installed capacity is still "only" 354 MW, most of it originating from the boom years in the nineties. No new power station will be connected to the grid in the current year. But in 2006 around 150 MW may come on stream. If these installations fulfil expectations regarding reliability and cost efficiency, it could lead to further exploitation of the enormous market potential and a surge in growth. It is still very difficult to give a quantitative forecast. The global market initiative for solar thermal power stations (CSP GMI)[25] wants to create new solar thermal capacities of around 5,000 MW by 2015. Given the current project status, this goal seems ambitious, but not impossible. As Table 25 shows, about 3000 MW of capacity should be achieved as early as 2008 if all the projects are successfully completed. But at the moment most of the projects are still at the stage of a feasibility study, which means the percentage of failures before final completion is likely to be relatively high. Realistically we therefore think capacity will only reach around 1,500 MW by 2008.

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[24] Concentrated Solar Thermal Power – Now! Greenpeace, ESTIA, Solarpaces, Brussels, September 2005

[25] GMI Broschüre, www.solarpaces.org

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