SARASIN

Sarasin Basic Report

Sarasin Sustainable Investment

Solar energy – sunny days ahead?

Current status and outlook for photovoltaics and solar thermal power

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Please see important information on last page.

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- Professor Peter Woditsch, Spokesman of the Executive Board, *Deutsche Solar AG*;
- Raffaele Piria, CEO of the *European Solar Thermal Industry Federation (ESTIF).*

Contents

Executive summary

Photovoltaics

Measured by annual production of solar cells and modules, the global market for photovoltaics grew 34% last year and continued this dynamic rate of growth in the first ten months of 2004. It is fair to say we are in the midst of a boom at present – one that we expect to continue for another 1-2 years before tailing off towards the end of the decade.

Germany is a very important contributor to this PV boom. Thanks to the successful revision of the Renewable Energy Law (EEG), which promises even more attractive fixed-rate payments for solar energy fed into the mains grid, growth in Germany especially will reach a record high this year, and this is bound to have a positive impact on global solar cell production as well. We therefore predict that the watermark of one gigawatt of solar cell production will be surpassed for the first time in 2004, with capacity expanding 50% to 1,125 MW.

But Germany's "solar miracle" cannot last forever. Firstly, the capacity of Germany's solar cell and module producers is growing faster than domestic demand, so the seller's market could soon turn into a buyer's market. And secondly, Japanese manufacturers in particular are expanding their capacities rapidly, and since their own domestic market is not big enough to absorb these new capacities, they will be forced to concentrate on export, so that competition is likely to hot up considerably in the medium term.

Apart from tougher competition from the Far East, another potential threat is likely to be a shortage of raw materials. Capacities for dedicated production of solar-grade silicon are only just being built up, and demand for the raw material silicon is increasing in the semiconductor industry as it recovers from its previous slump. So there may well be temporary bottlenecks and price hikes if solar cell production continues to rise.

The Japanese market, which has been a global motor for solar energy expansion in the past, faces a number of imponderables once the extremely successful RPVDP incentive programme finally comes to an end. The PV market is currently in a state of flux in the US. In structural terms, the most dynamic growth is currently to be found in the area of grid-connected systems, and this segment is still only being gradually built up in the US.

In the long term, however, the potential for photovoltaics is still a long way from being exhausted. In 8-10 years, technologies could be available that allow cost reductions over and above the steady cost cuts achieved through production optimisation (5% cost reduction advocated by the EEG). Our estimates show that, after a temporary breathing space, this will fuel further growth in the global PV industry from 2010 onwards, with annual cell production volumes increasing to 5,800 MW by 2020. This is equivalent to an average growth rate in annual cell production of 13% over the period 2003 to 2020.

Solar collectors

Solar thermal power is a fairly mature technology now. We can expect to see further technological innovation, especially in the area of solar cooling and hybrid systems. Over the last three years, average costs for solar collectors have fallen about 10%. The global solar collector market is heavily fragmented and there is very little information available about the companies. The German market has consolidated to a large extent: Three big companies together command a third of Germany's flat-panel collector market.

Last year the worldwide newly installed collector area rose 23% to 12.9 million m^2. Based on the new conversion factor of 0.7 kW_{th}/m^2, this equates to newly installed capacity of 9 GW_{th}. Three-quarters of this new capacity was installed in China, where demand continues to soar in tandem with the country's escalating energy requirements. The enormous demand in China is primarily due to its massive population. In terms of installed collector area per head of population, however, China is well behind the leading European countries as well as Israel, which has the world's highest per capita collector area. This comparison shows there is still plenty of room for the Chinese market to grow. In addition, Chinese manufacturers are increasingly exporting high-quality collectors to international markets.

Last year the entire European market grew 25%, and will continue to be dominated by three countries: Germany, Greece and Austria. These countries accounted for 80% of all products sold. This year, by contrast, we expect growth in Europe to plummet to just 7%, while it is only expected to reach 2% next year mainly because of the anticipated decline in newly installed collector area in Germany. In the German market especially there now seems to be a certain amount of competition between the increasingly popular photovoltaics and the supposedly "unspectacular" solar thermal power business.

The newly defined conversion factor of 0.7 kW_{th}/m^2 makes it far easier to compare solar energy with other forms of renewable energy. It also shows, for the first time, just how important solar thermal energy actually is. With a global installed capacity of 60 GW_{th} (2003, glazed collectors only) solar thermal energy is therefore more important than wind energy (2003: 40 GW_{el}) and well ahead of photovoltaics (2003, OECD countries: 1.8 GW_{el}).

Our long-term forecasts put global growth rates for solar thermal power at between 17% and 20% up to 2010. They will then gradually fall back to around 10% in the period from 2010 to 2020. Measured by newly installed area p.a., the market volume will grow to 160 million m^2 by 2020, with capacity rising to 112 GW_{th}.

Solar thermal power plants

Recently far more attention has again been paid to solar thermal power plants. Technological innovation and improved general energy policy conditions, especially in the US and Spain, have led to the creation of an impressive project pipeline, whose implantation could lead to approx. 3,000 MW capacity coming on stream before the end of the decade.

However, most of these projects are still in a very early planning stage, and their completion and success will be vital for the future of what is potentially a very interesting solar technology option.

We do not provide any forecasts for solar thermal power plants, but refer instead to a guide figure adopted for an industry initiative to install capacity of 5,000 MW by 2015. Although we are confident that this technology has long-term potential, particularly since it is the only solar technology option that could replace conventional thermal or nuclear power stations, we think this target is ambitious, but not altogether impossible.

Introduction

New concept is a proven success – our report covers the entire range of solar energy applications

Last year our report included for the first time a new chapter on the use of solar thermal energy. Because the general response was so favourable, we kept the same format this year and offer an overall view of solar energy alternatives. This study therefore not only looks at its usual core topic, photovoltaics, but also solar thermal energy applications – from traditional solar collectors to more innovative uses such as solar cooling – and provides a status report on the latest developments in the area of solar thermal power plants. This year we concentrate mainly on innovations and updates.

Short-term forecast for most important markets

To cater for the increased demand for regional forecasts, we are publishing for the first time a short-term forecast for the development of the PV market up to 2006 in the world's three major solar energy markets: Japan, Germany and the US. We also take a detailed look at the German market, since many of our readers come from the German-speaking parts of Europe.

Long-term forecast up to 2020

As usual, the PV section finishes with a long-term forecast for the global development of the PV market. Because we are rapidly approaching the middle of the decade, we have extended our forecasting period from 2010 to 2020.

Solar collectors with news from the major countries

In the section on solar collectors, this year we concentrate on the most important markets – China, Germany, Greece and Austria – but also on emerging markets such as Australia, Spain and France. We also provide a short-term forecast for the European solar thermal energy market. As with photovoltaics, we have extended our long-term forecasting period to 2020.

Latest project status for solar thermal power plants

The development of solar thermal power plants is not exactly racing ahead at present, so there is not much news to report on this front. We simply provide an update on the progress of all global projects currently under way.

Expert opinions on four selected topics

As another innovation this year, we have invited four leading experts in their specialist fields to contribute to our report. They describe the solar technologies and applications which they think will become increasingly important in future.

1 Photovoltaics (PV)

1.1 General overview of PV market in 2003

Review

In 2003 global solar cell production expanded 34%. Our forecast for 2003 was for a global PV market volume of 780 MWp, but figures published in the industry periodical *Photon* (March/April 04) reported a volume of almost 750 MWp, slightly below our estimate. Our forecast was therefore about 4% higher than the actual figure.

According to the latest figures from IEA PVPS, global solar cell production in OECD countries alone jumped from 520 MW in 2002 to 686 MW in 2003, equivalent to growth of 32%. Growth was much higher than average in Japan (approx. 50%) and Germany (77%), while production in the USA was even slightly down.[1]

The increase in production capacities was not as dynamic: According to IEA-PVPS figures these only rose about 17%, compared with more than 60% in the previous year. In particular, the new capacities announced by German manufacturers at the end of 2002 were not realised for the most part. One knock-on effect of this is certainly the shortage of cells and modules apparent in the current year and the unusually long delivery times this is causing for solar installations. However, the boom in the first half of 2004, especially in Germany, has got things moving again and triggered massive investments in some cases.

PV market booming in Germany

Last year Germany's PV market experienced dynamic growth rates, with 133 MW of newly installed power. This trend continued in the first half of 2004, with well over 100 MW added. While this growth was stimulated towards the end of 2003 by the expiry of the 100,000 Roofs Programme, the main factor fuelling this year's expansion has been the final revision of the Renewable Energy Law (EEG), with more generous fixed-rate payments for solar energy fed into the mains grid. In January the Minister of the Environment Trittin also announced that Germany intended to increase its R&D budget for photovoltaics to around EUR 100m p.a., almost four times more than the previous budget.

Prices stable and could rise temporarily

As expected, no further cost cuts were seen in 2003 or 2004 because of more acute shortages and supply bottlenecks. But prices did not rise either. Many manufacturers said that they did not exploit the strong demand in order to increase their prices, but most of them did not want to exclude such a step in future if the current excess demand continues. In the mid-term, industry experts reckon that prices will sink again in line with the annual degression in fixed-rate payments for solar energy fed into the mains grid.

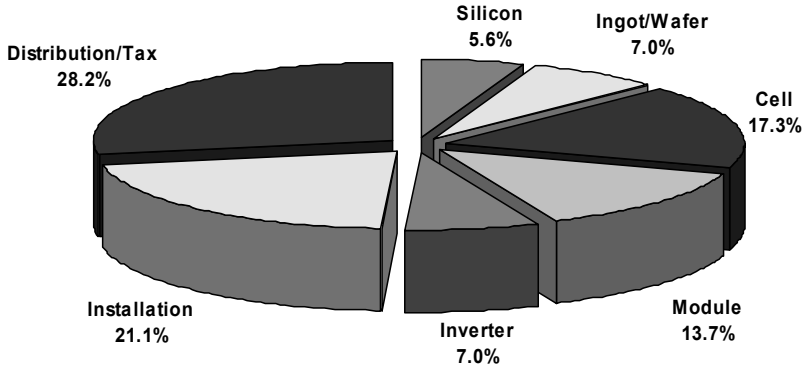
1 Trends in Photovoltaic Applications; Survey Report of selected IEA countries between 1992 and 2003. IEA Photovoltaic Power Systems Programme – Task 1; September 2004. Whenever we cite IEA-PVPS as a source, the information is usually taken from this publication.

1.2 Analysis of the individual stages of value added

Solar value added stages: Less than 50% for the PV segment

With solar power, the creation of added value starts with silicon and moves in a clockwise direction in Fig. 1 below. The apportionment of costs for an average PV installation is taken from a recent report on the photovoltaics industry.[2] Material costs (raw material, cell, module and inverter) account for around 50% of total net costs for a PV installation. The manufacturers of wafers, cells and modules which, as always, are the focus of our attention, only account for just under half the value creation of the entire PV market.

Fig. 1: Percentage of net costs in a PV installation



Source: CLSA, Rogol, July 2004

1.2.1 Solar-grade silicon and wafer production

Silicon, shortage of raw materials, prices

Up to the end of the nineties the PV industry, still relatively small at the time, was able to comfortably meet demand with scrap silicon from the semiconductor industry. Since then solar cell production has expanded about five times. Over the same period demand for solar-grade silicon has risen by a third, despite significant efficiency improvements in material usage (e.g. thinner wafers, etc.). Last year the solar industry already processed around 9,000 t of crystalline silicon. This surge in demand did not have a major impact on prices, partly because chipmakers suffered a massive slump around the turn of the millennium and suddenly required far less silicon. Manufacturers of pure silicon were quite happy to use their smelting furnaces at least some of the time for supplying the solar power industry. Because solar-grade silicon was readily available, the PV industry did not make enough of an effort to build up its own source of raw material supply that was independent from the semiconductor industry.

***Solar Grade Silicon* produces silicon for the PV industry**

The only company that has so far concentrated exclusively on the production of silicon for the PV industry is *Solar Grade Silicon LLC (SGS)* in the USA, a joint venture between Norway's *Renewable Energy Corporation* (REC) and America's *ASiMI LLC*. In 2003 *SGS* produced 2,000 t of solar-grade silicon for the first time.

2 Sun screen – Investment opportunities in solar power. Solar power sector outlook. CLSA Asia-Pacific; Michael Rogol, July 2004. The apportionment of costs is roughly similar to the well-known Bölkov report at the end of the nineties. Apparently the apportionment has not changed much.

SGS plans to continue to produce about 2,000-2,500 t of silicon in the coming years using the classic Siemens method.

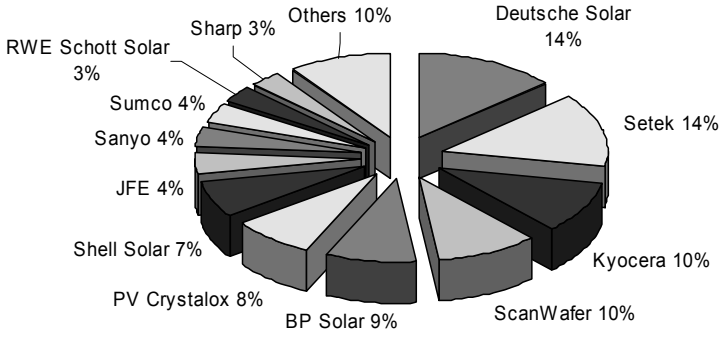
Other silicon producers

There are six other companies that currently produce solar-grade silicon. The most active are: *Hemlock*, USA; *Wacker*, Germany and *Tokuyama*, Japan. In 2003 all three supplied a substantial part of their production to the PV industry and also confirmed that they intended to target this industry more in the future (partly as a form of diversification) and would also like to develop new technologies to cater for its particular needs. In recent years these companies have also invested approximately one billion euros in expanding their capacities from 14,000 t to around 27,000 t at present.

Wafer producers

The same companies are often involved in the production of silicon ingots and wafers. According to IEA, the most important competitors in this area are Norway's *ScanWafer*, *Deutsche Solar* and *PV Crystalox*, an Anglo-German company. Figure 2 provides an overview of the leading wafer manufacturers for the solar industry.

Fig. 2: Market shares of leading wafer producers for 2004. Total capacity approx. 900 MW



Source: Prof. Peter Woditsch, Deutsche Solar, October 2004

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*, *Shell Solar* and *Photowatt*. Some competitors also use special technologies geared to their own solar cell production, such as the EFG method used by *RWE Schott Solar*.

Is the predicted shortage of raw material a threat?

At present the semiconductor industry requires around 20,000-21,000 t of pure silicon. By comparison, the PV industry requires around 10-12 t of silicon per megawatt, i.e. about 10,000-12,000 t for the installed capacity of one gigawatt expected in 2004. Solar cells do not require such a high degree of purity as semiconductors, and solar-grade silicon therefore fetches lower prices on the market than the pure silicon used for chip manufacture. Manufacturers prefer to sell their silicon to the semiconductor industry if they have a choice. The

semiconductor industry creates more added value and has greater "staying power", which means it is able to pay higher prices than the PV industry if both sectors increasingly have to fight over the same supply of very pure silicon as a raw material. More precisely, there is excess demand for the cheaper solar-grade silicon and this is certainly likely to bump up the price of this raw material. On the other hand, higher prices make investments in expanding (solar-grade) silicon production more attractive. But it usually takes 2-3 years to expand capacity. This could well mean that the growth of the PV market could be impaired by this raw material shortage – at least until the capacities within the solar production chain have balanced out again.

Alternative technologies will benefit

It is important to remember that the specific amount of raw material required to generate the same capacity is likely to continue to sink. 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. We are therefore confident that this temporary bottleneck in raw materials will be rectified soon – purely due to producers' self-interest in diversification.

1.3 Solar cell technologies

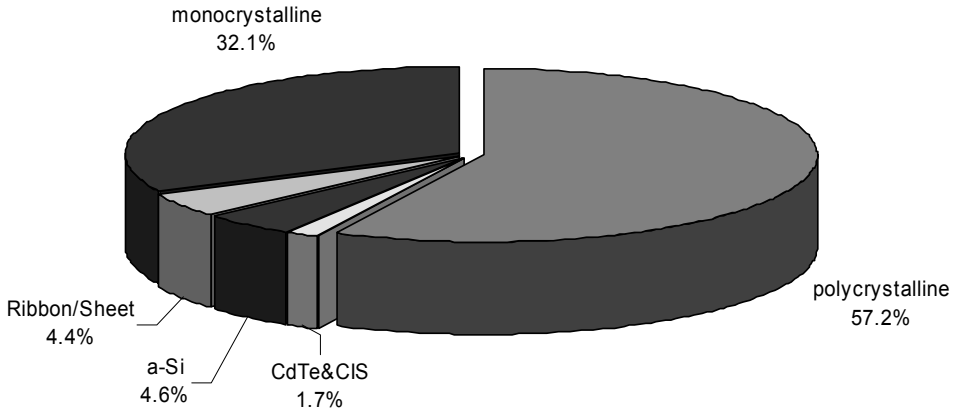
Optimisation of industrial production still a top priority

Technological breakthroughs and announcements about record effectiveness and new materials in research are almost part of the daily agenda 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. This assumption is confirmed by the fact that last year companies still relied mainly on established solar cell technologies, as Fig. 3 shows.

Not much technological innovation

In 2003 the picture for cell technologies was pretty much the same. Almost 90% of all solar cells produced were monocrystalline or polycrystalline silicon cells. Compared with last year, there has been a further shift in the direction of polycrystalline cells. Thin-film technologies (amorphous silicon, CdTe, CIS, etc.) stayed at a relatively modest level in 2003 as well.

Fig. 3: Share of different solar cell technology options of total global market volume 2003



Source: Photon International 3/4 2004

Despite optimisation, significant cost savings only possible with new technologies

However, as we already suggested in the section on the raw material situation, it is quite possible in future that thin-film technologies will gain more momentum as solar-grade silicon becomes more expensive and in short supply.

In the solar energy industry there are basically two strategies for cutting costs in PV cell and module production. In crystalline silicon technology, the focus is on the economy of scale effects provided by mass production, larger and thinner wafers and improved efficiency. Most providers do not attempt 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: The price per module has dropped by around 30% in the past four years. However, other industry pundits doubt that this is a feasible way of achieving the basic cost level for solar energy to be profitable, which is estimated at 1 EUR/Wp.

The second strategy manufacturers therefore pursue is to research innovative materials and technologies and try them out in pilot production. These measures require intensive research and are very risky, but the potential they offer is the achievement of cost savings in the long term to ensure that solar energy continues growing when crystalline silicon technology is exhausted or wafers are in short supply.

"Second-generation" CIS cells

Thin-film technologies, which do not use silicon, have been the subject of industrial trials since the end of the nineties. A lot of research is required to scale up the technologies developed in scientific laboratories into a commercially viable format, and so far no one has managed to build a respectable size of production facility.

Furthermore, the market has reservations about some of the new types of module, as they are judged to have a high heavy metal content. The *Hahn-Meitner-Institut* in Berlin has responded to these experiences and developed a new type of thin-film technology that has been adapted to suit technical production criteria and also has the advantage of being very environmentally friendly. The solar cells use the semiconductor copper indium sulphide ($CuInS_2$, or "CIS" for short) as absorber material and are therefore sometimes referred to as "second-generation" CIS cells in order to differentiate them from solar cells made of copper indium selenide.

This new CIS technology basically uses a sputter process to manufacture thin films – a technology that is used in the glass industry for surfaces up to 20 m² and provides a very homogeneous layer and good material quality. The construction of the cell is much simpler than copper indium selenide technology. The use of sulphur instead of selenium speeds up the production of the absorber, reduces energy consumption and simplifies the machine technology required. Weighed against these production advantages is only an average level of efficiency of 10% (5 x 5 cm² small module). This is because during development more value was placed on usability and low manufacturing costs than on a high degree of efficiency. The first goal is to provide competitively priced production with costs below 1.50 EUR/Wp, while the long-term target is to improve efficiency further and cut costs to below 1 EUR/Wp.

A consortium of scientists formerly with the *Hahn-Meitner-Institut* and a group of major investors is currently building a pilot production plant for the new CIS solar modules in Berlin. The partners include the energy company *Vattenfall Europe* and a subsidiary of *Jenoptik AG, M+W Zander*. The company founded by the consortium, *Sulfurcell,* plans to enter the market in 2006 with the new module type.

Dr Nikolaus Meyer, CEO of *Sulfurcell Solartechnik GmbH*

Approaches based on existing silicon cells

Another promising approach is to identify and rectify the weaknesses of conventional silicon technology. One of these is that traditional silicon cells become less efficient under intense illumination, i.e. when the sunlight is amplified with the help of solar concentrators.

Photovoltaic Solar Concentrators

Solar concentrators have always held out the promise of achieving price levels for solar electric generation that compete with current utility prices. The idea is simple enough: Since photovoltaic cells are its costliest components, the cost of a system can be reduced by increasing the power obtained per unit area of PV cells through using an inexpensive optical system to concentrate sunlight onto the cells.

To date this cost objective has not been achieved. Conventional mass-produced silicon PV cells do not retain their efficiency under concentrated illumination, which, in effect, defeats achieving the cost objective using such cells. This has led to the development of more efficient cells using advanced light trapping, complex emitter profiles, passivated surfaces etc. as well as multi-junction cells employing III-V semiconductor materials such as gallium arsenide. These advanced cells are more expensive to manufacture than conventional mass-produced silicon cells. The higher cost requires high concentration ratios in the range of 50x to 1000x in order to achieve sufficient power per unit area, which in turn leads to high tracking accuracy requirements.

The combination of these factors (more expensive cells, high concentration ratios, more complex optics etc.) leads to systems that are, at this time, no more price-competitive than simple flat panel based systems. Indeed, all of the operational medium-to-large scale systems that have been constructed to date utilise conventional flat panel PV technology. These systems are not cost competitive without subsidies such as feed-in tariffs, but the fact that flat panels are a proven technology has led to the recent construction of several such systems. Experimental concentrator systems using advanced cell technologies have been constructed. They also are not cost competitive, but the fact that they require new manufacturing infrastructure and are not seen as being "proven" has so far impeded them from being used in operational systems.

The principal cause of decreased performance of conventional silicon cells under concentrated illumination is the relatively high series resistance of the screen-printed front electrode. One of the first attempts to deal with this problem was the development of the laser-grooved buried contact (LGBC) cell. While this technology improved the conductivity of the cells, price competitiveness has not yet been achieved. A Canadian PV manufacturer, *Day4 Energy Inc.,* has developed another technology with the potential to realise cost competitive solar concentrators. Applying this technology to today's mass-produced photovoltaic cells results in a significant reduction of the series resistance of the cells. Prototype cells have been shown to retain their efficiency under concentrated illumination and therefore produce more power per unit area. Their cost is essentially the same as that of conventional PV cells and they can be produced using existing manufacturing infrastructure. The lower cost of these cells enables operation at relatively low concentration levels (<10x), which significantly lowers the cost of the concentrators, and hence the overall system cost.

Dr John MacDonald, CEO of *Day4 Energy Inc*.

1.4 Top ten solar cell producers

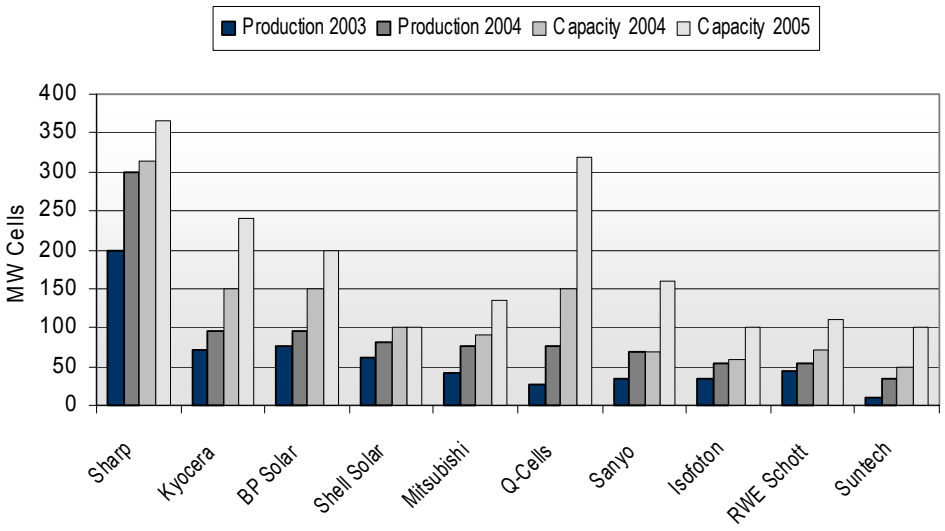
Top ten The overview in Fig. 4 shows the world's top ten solar cell manufacturers with the volumes they produced last year, estimated production in the current year, and planned capacities for y/e 2004 and 2005.

Sharp The Japanese electronics group *Sharp* was the world leader in solar cell production in 2003, with a market share of 26.6%. Last year it increased its production another 60% and this year it is aiming for another 50% rise, with planned production in excess of 300 MW. This summer the Japanese company opened another production plant in the UK. The Wrexham works, in North Wales, is *Sharp's* first module factory in Europe. The company predicts growing demand, particularly from Germany. The factory's production capacity was initially 20 MW p.a., but was already due to be expanded to 40 MW in October 2004. The module factory in Tennessee, USA is also set to double its capacity from 20 MW to 40 MW. The company also plans to recycle solar modules. Group turnover came to JPY 2300 billion, with solar cells accounting for JPY 73 billion, or around 3%.

Kyocera After a temporary phase of modest growth, *Kyocera* now wants to expand more aggressively again. Last year production capacities jumped 27% to 76 MW. Now *Kyocera* even plans to become the world's biggest fully integrated photovoltaics

company. To this end it has erected module factories in America and in Europe. In November 2003 production started in Tianjin, China. Capacity should reach 12 MW by the end of 2004. A new factory came on stream in Mexico this October with a capacity of 12 MW, and the aim is to expand this to 35 MW by y/e 2005. Plans in the Czech Republic are even more ambitious: the current capacity of 12 MW is due to be stepped up to 50-60 MW by y/e 2005. This means that the four major solar markets of Japan, Europe, USA and China can all be served from local production facilities. Cell production capacity in Japan is due to double to 240 MW by August 2005. Overall *Kyocera* plans to invest around JPY 10 billion (approx. EUR 70m).

Fig. 4: World's biggest solar cell producers and their expansion plans, ordered by estimated production volume in 2004



BP Solar

BP Solar is a wholly owned subsidiary of the global energy group *BP* and employs over 2,000 people worldwide. Its 2003 global production capacity was 32% higher than the previous year, rising to 94 MW. *BP Solar* has just expanded its factory in Spain at a cost of USD 100m, increased the flexibility of its production facility in the US and opened new production lines in India, Australia and the USA. Over the next 12-18 months it plans to expand capacity to around 200 MW. *BP Solar* is heavily involved with building large installations in open spaces in Germany. It opened a 4 MW solar power plant in Sachsen-Anhalt in September. In Bavaria it is planning a 1.5 MW large plant on the site of a filled-in quarry.

Shell Solar

As announced, *Shell* closed down the production plant it acquired from *Siemens* in Munich and the one in Helmond (NL) and is now concentrating its German cell production in Gelsenkirchen. In addition to solar cell production (80 MW in 2004), *Shell Solar* is also becoming increasingly involved in the implementation of large projects. *Shell Solar* has built a 1.8 MW PV installation in Bavaria, in conjunction with *BGZ (Beteiligungsgesellschaft Zukunftsenergien AG)*.

Mitsubishi Electric The Japanese technology group *Mitsubishi Electric*, which only started manufacturing polycrystalline cells in 2000, wants to expand its production capacities for cells and modules in response to the success of other Japanese competitors in growing their sales. The annual output of the factories in Nakatsugawa and Kyoto is due to be increased from 90 MW to 135 MW by April 2005. By 2006 the company wants to build a production system with a capacity of 230 MW. In the current year *Mitsubishi Electric*'s PV sales should be more than double last year.

Q-Cells For the first time since our report has covered the global solar cell market, *Q-Cells* – a German "pure player" has made it into the top ten. The company was only founded three years ago, and wants to increase its production by more than 160% this year as well. In June *Q-Cells* made the first upgrade to its growth forecast. Instead of 60 MW, production will rise to 75 MW this year. In 2002 production was only a mere 9 MW. *Q-Cells* has therefore shown by far the highest percentage growth rates of all the manufacturers. This year *Q-Cells* plans to invest EUR 40m, and EUR 50m next year to push production up to around 200 MW. With the opening of a fourth production line, the company should become Europe's biggest manufacturer of solar cells in 2005.

Sanyo As a reaction to the expanding PV market, *Sanyo Electric* has also announced its intention to expand its production capacities more aggressively in future. Capacities for its HIT technology will soon be increased to 153 MW. In August its Japanese factory in Shimane started to expand capacity from 30 to 50 MW (scheduled for completion in March 2005). The expansion of the factory in Nishikinohama from 33 MW to 103 MW is due to be completed in January 2005. In 2004 module production in Mexico was almost at the limits of its capacity of 10 MW. Production capacity of amorphous solar cells is also set to increase from 5 to 7 MW.

Isofotón The Spanish solar energy company *Isofotón* has opened two new branches in Italy and wants to build up a national distribution and service network there in the long term. *Isofotón* wants to offer not just specialist advice and technical support for projects, but fit entire installations itself and hand them over as turnkey projects. Apart from Spain and Italy, *Isofotón* is represented as a solar energy provider in 48 other countries. In December it is due to open a new 25,000 m^2 factory in Malaga. Once the new lines come on stream, the company also plans to transfer its existing lines from the old factory. This will help boost annual cell production from 55 MW at y/e 2004 to 120 MW at y/e 2006.

RWE Schott Solar *RWE Schott Solar* wants to invest EUR 40m in an expansion drive. As well as the already announced plan to build two new cell production lines in Alzenau (Germany) each offering 20 MW capacity, RWE also wants to increase production for solar modules in the Czech Republic with two lines offering a total output of more than 40 MW p.a. Production is scheduled to start in mid-2005 and will reach some 15 MW by year-end. Total capacity for cell production will

therefore be expanded at a rate of more than 40 MW p.a. to 110 MW (incl. 10 MW crystalline cells in the USA).

Suntech

Suntech Power is a Chinese-Australian joint venture based in Shanghai. The company has only been trading for three years and this year its production is around 35 MW polycrystalline and monocrystalline solar cells. The company assembles most of these cells itself into proprietary solar modules. *Suntech* has ambitious expansion plans: By the end of 2004 it wants to increase capacity to 50 MW, and then double this figure to 100 MW by year-end 2005.

Other companies: Deutsche Cell (SolarWorld), Evergreen Solar, GE Energy, Photowatt (ATS), Sunways ...

This summer *Deutsche Cell*, a subsidiary of *SolarWorld,* announced investments of EUR 150m for expanding its production capacities. At its site in Freiberg (Saxony) it wants to double annual wafer production to 240 MW by 2007, quadruple solar cell capacity to 120 MW and more than double module production in Freiberg and Gällivare (Sweden) to 120 MW. This year *Deutsche Cell* will produce 30 MW solar cells. *SolarWorld* recently rejected a takeover bid from the US conglomerate *General Electric (GE)*. Having taken over *Astropower,* it looks as if *GE* wants to break into the European solar industry as well. *Astropower* seems to have a new lease of life following its takeover by *GE Energy,* but no details are available yet on production and future expansion of capacities.

ErSol, a cell and module manufacturer based in Erfurt, produced cells with a total capacity of 9 MW last year and wants to increase this to around 16 MW this year. Capacity will be expanded to 50 MW by the end of 2005. But it remains to be seen to what extent *ErSol* will be affected by the financial difficulties experienced by its parent company *Umweltkontor Renewable Energy AG*, which filed for bankruptcy this summer.

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.

Last year the Japanese conglomerate *Kaneka* produced 14 MW amorphous silicon thin-film cells. These cells are only around 0.3 μm [micrometers] thick, compared with 200 μm for a normal crystalline silicon cell. The company's production target for this year is around 20 MW.

Last year *Motech* produced around 17 MW crystalline solar cells in Taiwan. This year it expects to increase this to 34 MW and continue to rapidly expand capacity up to 125 MW by the end of 2005.

The Canadian group *Automation Tooling Systems (ATS)* has a solar energy business called *Photowatt* that has almost doubled its sales to USD 88.5m. 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 20 MW. It has highly automated production lines that manufacture flexible solar cells in different colours. SSP is based on crystalline silicon.

Sunways AG, a producer of solar technology based in Konstanz, plans to build a new factory in Thüringen. The new production line for solar cells in Arnstadt should create 60 new jobs. The company aims to build a modern production

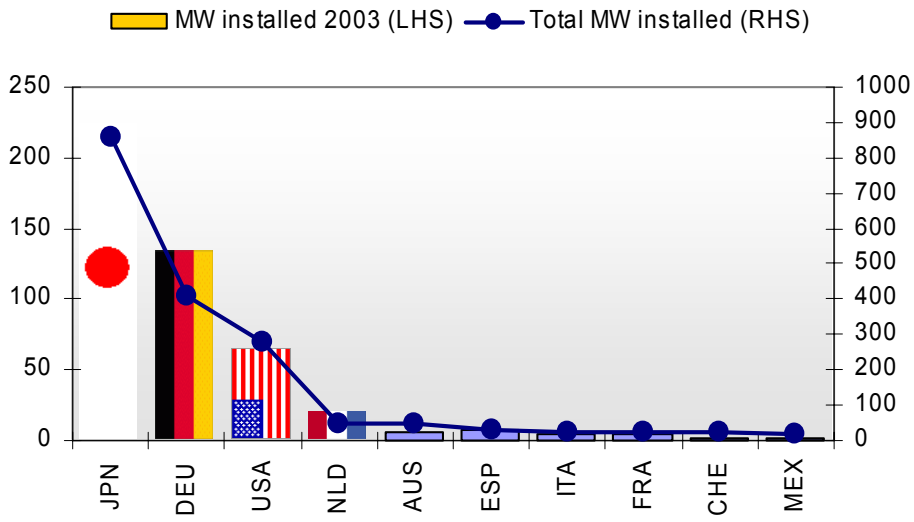
facility with four shifts working 24/7. The new plant has a capacity of 30 MW and will manufacture monocrystalline and polycrystalline solar cells. There are plans to expand capacity up to 80 MW. Production is scheduled to start in summer 2005, with full production capacity reached by January 2006.

1.5 The major PV markets

Japan, Germany and USA still dominate

The dominant nations in installing PV capacity are still Japan, Germany and the US (in that order). These three countries were responsible for about 88% of the newly installed capacity in OECD countries during 2003. If we include the small but rapidly growing Dutch market, these four leading nations account for as much as 92% of all PV installations (same reference basis).

Fig. 5: Newly installed in 2003 and cumulative PV capacity at y/e 2003 in the ten biggest OECD countries



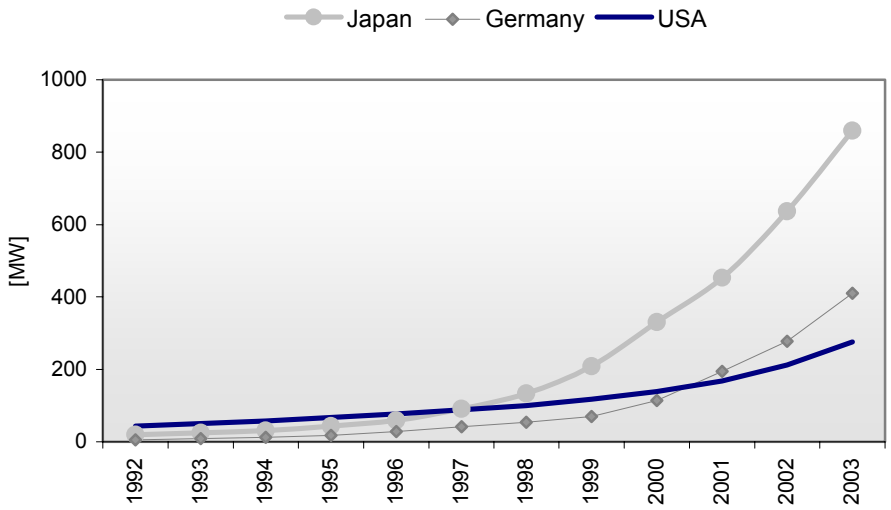
Source: IEA-PVPS

These countries have enjoyed a dominant position, as reflected in the cumulative totals for installed capacity. Japan leads Germany and the USA, and this group is well ahead of the Netherlands and Australia. In terms of cumulative capacity, these five countries account for more than 90% of the total capacity installed in OECD countries. Fig. 5 illustrates this strong geographical concentration.

US continues to lose ground

Traditionally – at least up to the second half of the nineties – the USA was always the leader in terms of installed PV capacity. Then the more consistent research and promotional efforts of the Japanese began to pay off and in 1997 for the first time Japan moved ahead of the US, which four years later was overtaken by Germany as well. The expected expansion rates for the coming years in both Japan and Germany are much higher than the US. The gap between the top two and the US is therefore set to widen even further (Fig. 6).

Fig. 6: Historical development of cumulative installed PV capacity in the three biggest markets: Japan, Germany and the USA

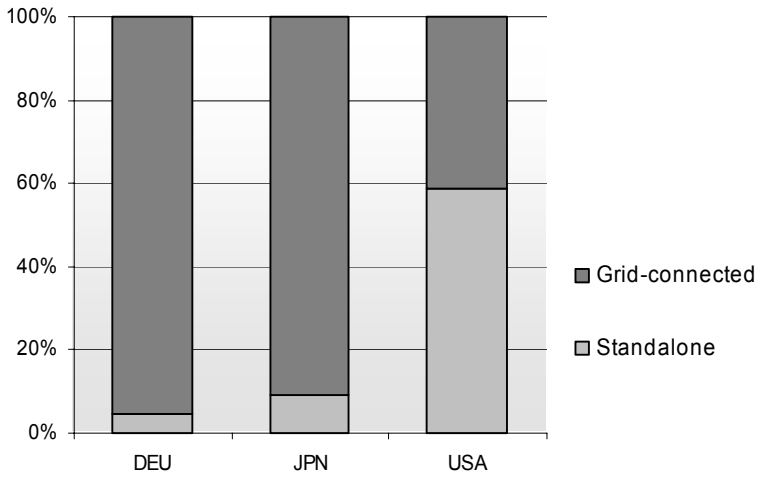


Source: IEA-PVPS

Structure of America's PV market is a drawback

The reason for the contrasting development of these three countries becomes clearer if we bear in mind that the segment which is currently enjoying by far the biggest growth rates is grid-connected solar energy systems. The percentage of off-grid installations is very small in both Japan and Germany. Although this quota is gradually falling in the US, it is still around 60% (Fig. 7). All the incentive programmes that make not just the installation but especially the operation of solar systems attractive through fixed-rate payments for solar energy fed into the mains grid (Germany's Renewable Energies Law (EEG) is a prime example) naturally favour grid-connected systems. To this extent the lower rate of growth in the US is also the result of this "structural" disadvantage.

Fig. 7: Structure of the PV market in Japan and Germany vs. the USA at y/e 2003



Source: consolidated as per IEA-PVPS

Analysis of top three PV markets: Japan, Germany and USA

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

1.5.1 Japan

Solar energy as a constituent of overriding energy targets

In Japan, incentives to promote PV are an integral part of national energy policy. Two years ago the Japanese parliament passed an energy framework law based on the following main pillars: (1) stable energy supply, (2) environmental friendliness and (3) market mechanisms. Photovoltaics is explicitly named as a means of achieving the second goal. In Japan – in sharp contrast to the USA – the Kyoto protocol also plays a very important role. The government is committed to achieving a 7% reduction in 1990 CO_2 emissions. PV has been expressly named as a means of making this reduction. In July the *Ministry of Economy, Trade and Industry* (METI) published a new document on Japan's energy future in 2030. It envisages renewable energies accounting for 10% of total energy needs, with more than half of this – approx. 80 GW – provided by photovoltaics. A more concrete interim target of 4.8 GW installed PV capacity has been set for 2010. The *New Energy and Industrial Technology Development Organization* (NEDO) has also set a very ambitious target in its latest plan: 100 GW PV capacities by 2030.

RPVD programme extended to March 2006 – but what comes after that?

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 steadily falling subsidies for each solar system installed (900 JPY/W in 2003; 450 JPY/W in 2004), Japan has found a good balance between costs for individual consumers and state spending. The market for PV systems up to 10 kW has gradually grown. Newly installed capacity of 200 MW is predicted for FY 2004 within the framework of the RPVDP. This programme is due to continue to the end of FY 2006, but it's not yet clear what will come after that. The end of the programme is not a big worry per se, but this national subsidy programme is also closely linked to several local initiatives whose fate is uncertain as well. Japanese utility companies have also announced that they would only extend their voluntary *Net-Metering System,* which compensates customers for feeding solar energy into the mains grid, if the government maintains its PV subsidisation programme.

Can the industry survive without subsidies?

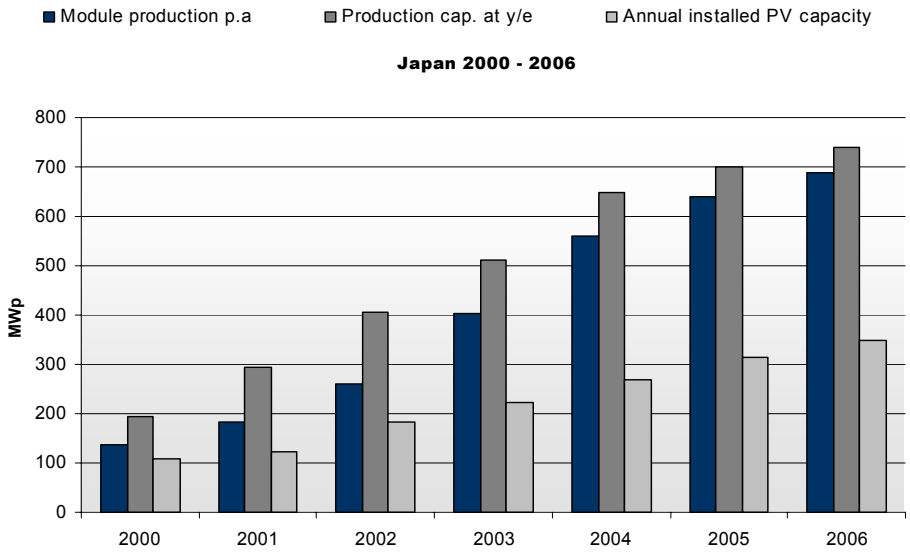
Instead of subsidising PV systems for residential buildings, the METI is planning a programme of subsidies for 30 - 50 kW systems mounted on public buildings, schools, factories and office premises. The details are still being worked out, but a proposal is due to be included in the budget as early as FY 2005. An existing programme is therefore coming to an end, while new subsidies are planned for a different category of solar installation. The Japanese PV industry could be facing difficult times. If the investment subsidy provided by the government is stopped, and with it the fixed-payments to homes paid by utility companies for solar energy fed in to the grid, the worst-case scenario would be a collapse of the

entire market. The key question is whether the PV industry will be strong enough to stand completely on its own feet by the end of 2006 (Fig. 8). It's also important not to forget the risk of higher interest rates. Higher interest payments on loans and mortgages could have a negative impact on the decision of many house owners and businessmen on whether to fit a PV system.

Heavy export pressure likely

Because capacities in module production have expanded so dramatically, it is likely that Japanese manufacturers will step up their export activity in the next two to three years. If we deduct the predicted volume installed in Japan from the total estimated production volume, there is a "shortfall" the same size as the entire global PV market in 2000, or half the cells produced in 2003. Because German manufacturers are also about to outgrow their domestic market (see below), it is possible that the current seller's market with its stable prices might temporarily turn back into a buyer's market with accompanying pressure on margins and possibly substantial consolidation among players.

Fig. 8: Short and mid-term market forecast for PV modules in Japan



Data up to 2003 reconstructed from IEA-PVPS, 2004 onwards: Sarasin estimates

1.5.2 Germany

EEG main stimulus for Germany's solar industry

Since the start of the year developments have been very positive for the solar industry in Germany as far as the overall conditions are concerned. The new law setting feed-in tariffs for solar power came into force on 1 January 2004, providing a seamless transition to the revised Renewable Energy Law (EEG) which took effect on 1 August 2004. The new regulations for solar power replace the parallel 100,000 Roofs Programme (investment subsidy) which ended in 2003, and raise the tariffs for solar power fed into the mains grid. In future solar

energy installations will pay for themselves purely thanks to more generous fixed payments. The strong market growth in the first half of the year and the full order books of module producers show that people are very keen to invest in modern green technologies if the financial incentives are attractive enough. A representative survey conducted in August by the Emnid Institut on environmental issues commissioned by *Greenpeace Magazine* confirms this assumption: According to the survey, 90% of the population views wasting energy resources as the biggest environmental problem, 59% think that the promotion of renewable energies should be stepped up, and 26% believe they are fine as they are. This confirms the general public's high acceptance of renewable energies.

Massive capacity expansion by producers of modules and cells

In the past five years German manufacturers have invested a total of more than one billion euros in setting up new capacities for PV cell and module production. The companies that benefited most from the boom experienced this year in Germany in particular were naturally those that had expanded their capacities well in advance and were able to bring them up to full utilisation in 2004. According to information from German companies, production capacities are likely to have expanded by over 50% by the end of the year. Most PV cell and module producers are also facing more major investment decisions. A further expansion in capacity is therefore expected by the end of 2005 and beyond.

German producers focus more on exports

If we compare the production figures of German module manufacturers with the PV capacity installed in Germany, we can see that almost half the installed solar modules were still imported in 2003. This was due to capacity bottlenecks at domestic producers and increased activity of Japanese providers on the European market, supported to some extent by the yen's favourable exchange rate versus the euro. At the moment, however, the capacities of German manufacturers are growing faster than the domestic market, i.e. companies have apparently decided to expand their market shares at home and abroad. Important export markets being targeted include the Netherlands, Spain, France, Italy, Austria, Greece and Cyprus. Some of these countries have also created subsidy programmes for solar installations. German manufacturers are also likely to be attracted to the growing market potential of India and China, and possibly also the USA for a short time (see what follows). Our forecasts show that German production will easily outstrip installed domestic capacity as early as 2006 (see Fig. 9). It is therefore essential for the German solar industry to expand its international distribution network and significantly increase its export quota.

Annual cost reduction of 5% is achievable

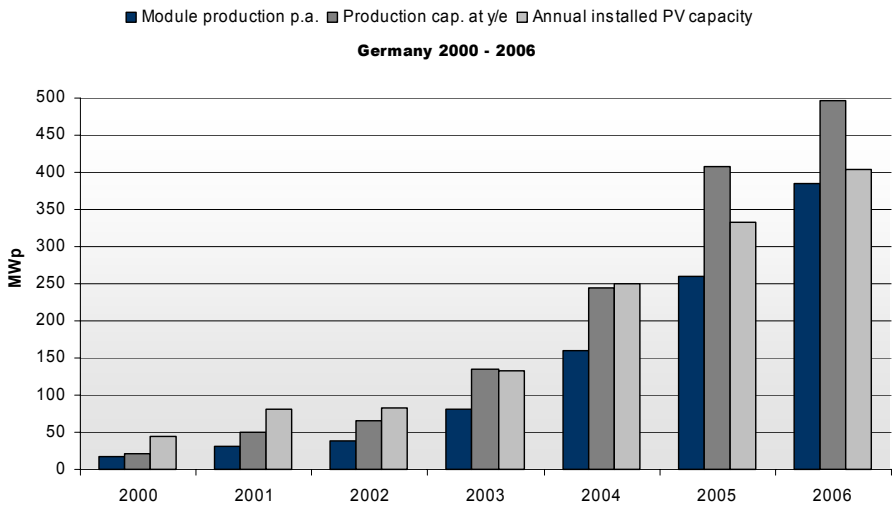
Thanks to the optimisation as a result of increased capacity and efficiency, German companies are very cost competitive internationally. An annual cost reduction of 5%, as required by the EEG, ought to be achievable. Although no further cost-cutting was done due to excess demand, a survey by the *Internationales Wirtschaftsforum Regenerative Energien* (IWR) shows that prices for PV systems up to 10 kW in Germany have fallen from around EUR 14,000 in 1991 to less than EUR 6,000 (2004) per installed kilowatt. Over

the past 13 years an average cost reduction of 6.3% p.a. has therefore been achieved.

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

In view of the expansion plans of German module producers, we expect production capacities to rise over the next three years from 135 MW (y/e 2003), to 245 MW (2004), 405 MW (2005) and around 500 MW (2006). Over the same period module production is set to increase from 80 MW (2003) to 380 MW (2006). The dynamic growth trend for PV systems installed in Germany is expected to continue. Annual newly installed capacity is likely to rise from 133 MW (y/e 2003) to 250 MW (2004), 330 MW (2005) and 400 MW (2006). From 2005 onwards Germany will therefore install more new PV capacity than Japan.

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



Basis: Survey of manufacturers; BSi, IEA and published information and own estimates

The circle of listed solar companies could grow soon

Investors should benefit 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 *Phönix SonnenStrom* announced plans for an IPO, other companies are apparently contemplating such a move as well. *Conergy* is already in talks with "various banks" and *Q-Cells* is also openly considering the possibility of an IPO.

Longer-term outlook

Prospects are good for the coming years up to 2010 thanks to reliable incentive programmes in Germany and expansion into other European countries. Even so, we expect the capacities effectively added in the next few years to be lower than manufacturers' plans. This trend can be deduced from past experience and is actually not such a bad thing, since a more moderate pace of expansion is likely to prevent a situation in which the solar industry – like a hot-headed Icarus – flies too close to the sun and crashes to earth. In such a dynamic market as the PV industry it is not unusual to have temporary periods of oversupply or over-demand, and subsequently volatile market conditions.

Viewed over the longer term, the reduction of energy generation costs is likely to be a critical factor in the further development of the PV industry. Companies should take advantage of the present comfortable situation to reduce their dependency on public subsidies over the medium to long term. In Germany, where the market benefits from the most favourable incentives in the world, we cannot rule out, for example, that a change of government could lead to amendments to the recently passed Renewable Energy Law (EEG). However, we do not expect any fundamental change to the basic thrust of Germany's energy policy, which is geared towards greater use of renewables, since this is part of an EU-wide policy. As with Japan, Germany is exposed to the risk of higher interest rates that could curb demand for PV systems.

It is difficult to say yet whether the solar industry could also be affected by the same sort of acceptance problems in the population that wind power has encountered in some cases (disfigurement of the landscape). However, we can expect an increase in the number of large installations in open spaces in response to more favourable subsidies in Germany.

Germany as 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 forerunner for the achievement of the goals set by the EU for renewables in its White Paper in 1997: The percentage of renewables used is to be increased from 6% to 12% by 2010 across the whole of Europe. The European Renewable Energy Council (EREC) has analysed the development of renewables in Europe in more detail.[3] Photovoltaics enjoyed an annual growth rate of more than 35% over the period 1995 to 2001. To achieve the target of 3 GW in 2010, growth has to continue at a rate of more than 30% p.a. This is an ambitious target, and we think the political and legal framework needed for its attainment is not yet in place in many countries.

1.5.3 USA

Fundamentally different market structure to Europe and Japan

Off-grid systems are far more important in the US than they are in Germany and Japan (see Fig. 7). In addition, there is no uniform subsidy programme that applies nationwide. At present such a solution is also extremely unlikely for political reasons, as demonstrated by the reluctance to renew the *Production Tax Credit* (PTC), a subsidy that is particularly important for wind power in the USA. However, individual federal states have a broad range of incentive programmes, ranging from tax allowances to fixed-rate payments in the sense of *Net-Metering* for renewable energies and for PV systems especially. [4]

3 Renewable Energy Target for Europe, 20% by 2020; European Renewable Energy Council (EREC), January 2004

4 www.dsireusa.org; Database of State Incentives for Renewable Energy (DSIRE)

California: the Golden State in more ways than one...

In 2003 California once again clearly asserted its role as the leading state in PV systems, with newly installed grid-connected capacity of 27 MW. The various incentive programmes contributed to this result to different degrees: The PV 'buy down' programme led to the installation of 12.3 MW of grid-connected systems on residential and commercial buildings.

- The subsidy programme of Sacramento's public utility company (SMUD) completed the second phase of its PV Pioneer Program, leading to the installation of systems with a capacity of 400 kW last year. Over the last ten years PV systems with a total of 11 MW capacity have been installed under the SMUD programme.
- The programme of subsidies of the public utilities companies of the city of Los Angeles (LADWP) led to the installation 3.8 MW new capacity in 2003, thanks to generous contributions of up to USD 5.50/Wp. Overall, some 7.5 MW can be attributed to the LADWP initiative.
- Another initiative, the California Public Utilities RPS Program, whose members include *Pacific Gas & Electric*, *Southern California Edison*, *San Diego Gas & Electric* and *Southern California Gas* installed around 9.9 MW in 2003.

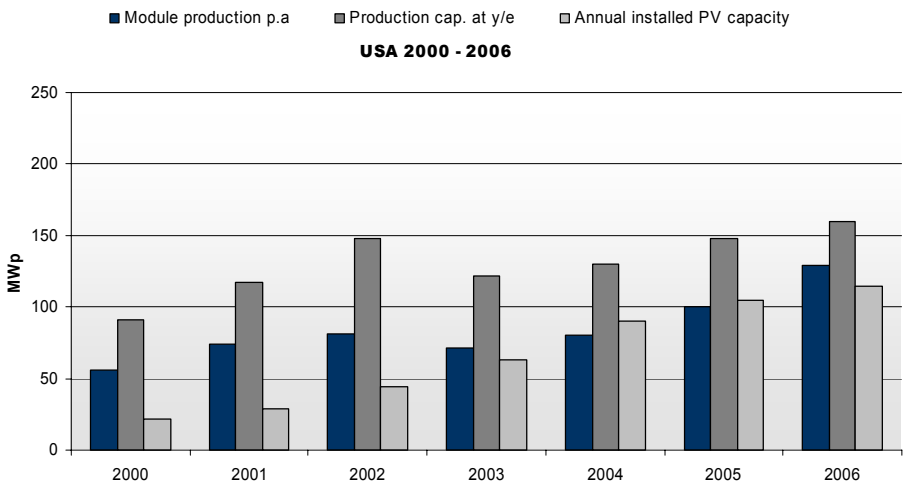
Cell and module production declined in 2003

Last year cells with a capacity of 102 MW and modules with a capacity of 71 MW were produced in the US. After two decades of continuous growth, this was the first year production fell, by 18.6% in the case of cells and 14% for modules. This decline was mainly due to two events. First, America's second biggest manufacturer of cells and modules, *Astropower*, had to file for bankruptcy – the company has since been taken over by *GE Energy*. Second, *Shell Solar* has repurchased substantial quantities of cells for its own module production, and these do not show up in the sales figures. In the past the US photovoltaics industry has been heavily export oriented. In 2003 capacity of 18 MW was imported and 54 MW exported, equivalent to exports of 36 MW. Half the cells and modules went to Germany.

Four more years without a major nationwide incentive programme

America's national policy for photovoltaics only plays a subordinate role, because the individual states are so independent and because the incentive programmes tend to be mainly federal ones. It is true that an election victory by Kerry may well have encouraged a move to reduce the country's dependency on oil and promote renewable energies. But even the Bush administration, which is friendly towards the oil industry, has always treated renewable energies fairly favourably in the past. It does at least seem that photovoltaics is very compatible with the current position of the US administration to tackle the problem of greenhouse gases mainly through technological advances rather than through international treaties. Reducing dependency on raw materials imported from abroad is very much in the interests of the Bush administration.

Fig. 10: Short and mid-term market forecast for PV modules in the USA



Data up to 2003 reconstructed from IEA-PVPS, 2004 onwards: Sarasin estimates

Consolidation in the US PV industry and surplus imports

On the manufacturing side, America's PV industry is suffering a crisis, brought on primarily by the commotion created by the collapse of the biggest independent PV producer, *AstroPower*. We expect the US to be the only market in the world's top three where domestic production cannot quite keep up with domestic demand. This could make the USA an attractive market especially for Japanese and German module producers over the next two to three years. The shortfall in supply is not that big, however.

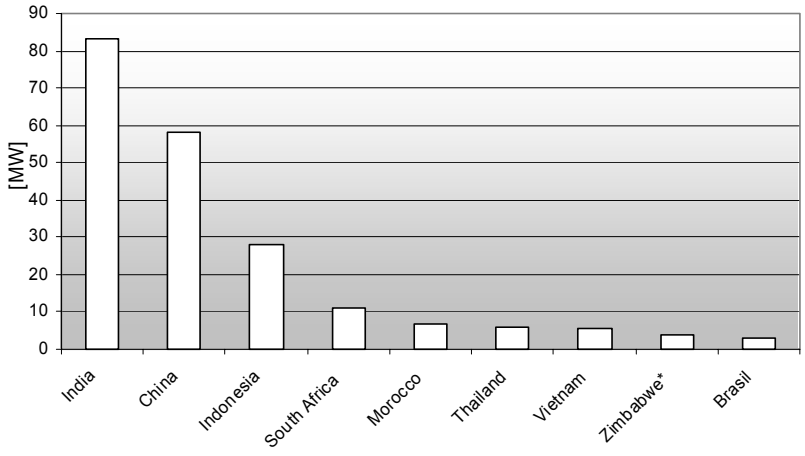
1.5.4 Development in non-OECD countries

Development in non-OECD countries

According to information from IEA-PVPS, the use of photovoltaics in countries outside the OECD is mainly limited to smaller residential systems (*solar home systems*) and applications on public buildings such as hospitals, schools, water utilities and telecommunications. In contrast to the major markets in industrialised countries (except the USA), off-grid systems are mainly used in developing and newly industrialised countries (Fig. 11). This latter market is still relatively modest at the moment, but holds big potential for the future because of the tendency for dynamic economic growth rates and particularly favourable sunshine levels in these countries. In total these countries already had over 200 MW capacity (cumulative) installed in 2003, equivalent to 11% of the PV capacity installed in OECD countries.

China's dynamic pace of economic growth, for example, means it has a huge energy requirement which it would increasingly like to meet through the use of renewable energies, particularly in view of the acute problems of local air pollution. China is aiming for a cumulative installed capacity of over 300 MW in 2005. By comparison, about 400 MW capacity was installed in Germany at year-end 2003.

Fig. 11: Total installed PV capacity (cumulative) in non-OECD countries



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

Production in non-OECD countries shows high percentage increases

According to IEA-PVPS, non-OECD countries produced cells with a capacity of around 64 MW in 2003, an increase of 24 MW or 60% on 2002. This 64 MW corresponds to around 9% of global cell production.

Potential in China, India and Malaysia

Last year capacities in China rose to 30 MW, and should reach 60-100 MW this year. The company *Baoding Yingli* is currently China's biggest producer of PV cells and modules (cell production capacity 16 MW). Other companies have increased their output to 10 MW: *Wuxi Snitch Solar Power* (cells), *Kyocera* and *Xi'an Jiayang* (modules). Others have an output of 12 MW*: Shandong Linuo, Shenzhen Clean Energy* (both cells and modules). In the past China not only had a relatively modest level of cell and module production, but also produced very little of its own solar-grade silicon (total ingot and wafer production approx. 60 MW).

India's solar market is dominated by *TATA BP Solar*. The company has a module production capacity of 38 MW, which corresponds to 50% of national production, but last year it only produced 20 MW. Other manufacturers, such as *WEBEL* or *Maharishi Solar Technology,* produced modules with a total capacity of 4.5 MW and 3 MW respectively in 2003.

Malaysia's *Mayang Kukuh* wants to invest around USD 100m over the next five years to build up its thin-film cell production based on the use of copper indium gallium diselenide (CIGS).

1.6 Development of the PV Market up to 2020

Sarasin's 2003 forecast was slightly too high for the first time

As we mentioned at the start of this report, the forecast of 779 MW we gave last year for the global photovoltaics market was slightly too high, by roughly 4%. In particular, solar cell production in the USA was much lower than we expected. The decline in production is partly attributable to the difficulties experienced by *Astropower*. By contrast, our forecast for Germany was slightly on the low side. In particular the production volumes reported by *Q-Cells* and *Deutsche Cell* were higher than we expected. Our forecasts for Japan were on target, and in our experience the data provided by manufacturers tend to be very accurate. We overestimated production in the rest of the world, and expected more from China in particular. It seems that the country's huge economic boom will take a while to make its impact felt on renewable energies.

Solar cell production reaches 1125 MW n 2004

We think the production capacity of new solar cells in 2004 will break through the one gigawatt barrier for the first time. With an estimated capacity of 1,125 MW, the market is set to grow at more than 50%.

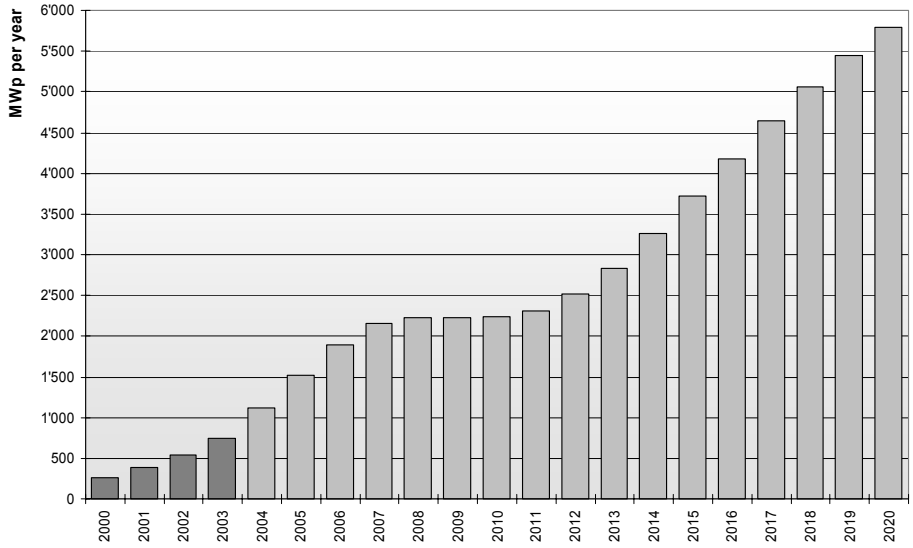
Pause for breath

For the first time, this year's report includes a long-term forecast up to 2020. This shows growth flattening off strongly from 2008 to 2010, before picking up again sharply. The reasons for this temporary lull in growth are as follows:

- Temporary bottlenecks in the supply of solar-grade silicon over the next one to three years could endanger cost reductions and have a negative impact on demand, capacity utilisation, and subsequently on further expansion of existing capacities.
- The US market will continue to lose ground against Europe and Japan because of its disadvantageous structure. A trend reversal takes time.
- Difficult 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.
- The ability of existing technologies to help reduce costs is constant, but limited. Only in the longer term do we expect sharp cost reductions through new technologies.
- Increasing competition from within their own camp in the form of alternative solar technologies such as solar power plants.

In the longer term, however the potential offered by photovoltaics is still far from being exhausted. We therefore see the temporary lull in growth more as a pause for breath rather than a turning point. We expect costs to be significantly reduced as a result of advances in manufacturing technology (bigger units, automation) and 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 almost treble from 2.2 GW in 2010 to around 5.8 GW in 2020. This implies an average growth rate of 13% p.a. in cell production over the period 2003 to 2020.

Fig. 12: Sarasin forecast for global solar cell production in MW up to 2020



Oil price has a limited impact

It is often debated to what extent the current oil price hikes will stimulate solar energy growth. At least as far as photovoltaics is concerned, this connection is more of a psychological one, because it draws attention to our high dependency on foreign oil imports and the often underestimated price risks of crude oil as a resource, and in doing so helps to drum up political support for incentives to encourage renewable energies. To this extent higher oil prices are not irrelevant for the development of the photovoltaics market, but are not as critical as generally assumed in the past. The only area in which oil prices have an immediate impact on demand for PV is hybrid systems, i.e. anywhere that photovoltaics can be used to replace or supplement diesel generators. However, 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 important factor, however. Nevertheless, the economic substitution mechanism is only likely to show a measurable impact if the oil price stays high for quite some time, or at least people expect it to remain high.

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2 Solar collectors

Overview

The second section of our report – as in 2003 – deals with the active use 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 issue we concentrate on technological innovations, provide a market overview and update our forecasts.

2.1 Technological innovations

Broad range of applications for solar technology

Thermal solar systems are currently used mainly for heating water and building interiors. But they can also be used for other applications, such as heating for industrial processes or to cool buildings.

Hybrid collectors

A newer idea is the hybrid collector, a combination of photovoltaics and solar thermal power. How it works: In summer, water-cooled PV modules supply substantially more power, and the water that is heated as it circulates around the collector is channelled for use as hot water in the building. The advantage is a combined electricity and heating system that is particularly suitable for single or multiple occupancy dwellings. However, research into this synergy effect is still in the early stages, and no commercial products are available at the moment. There are still a number of technical hurdles to overcome.

An innovative use from the USA: Power Roof™ from Solargenix

The US company *Solargenix* is developing another technical innovation. Its Power Roof™ system is a new concept: a roof fitted with a high-temperature solar collector. Concentration of the sunlight allows temperatures in excess of 400°C to be achieved. This energy can be used in the form of steam for industrial applications, sorption-assisted cooling, desalination, water purification, or space heating and hot water.

Market of the future: solar cooling

Something that is common in other areas – using thermal energy for cooling – is a very promising option for solar thermal power as well: solar thermal energy can be used to power cooling systems. There are different types of solar cooling technologies, whereby a distinction has to be made between refrigeration and air conditioning. A typical example is sorption-assisted air conditioning.

Saving energy through "solar-assisted cooling"

Worldwide about 100 million stationary cooling systems are sold, plus another 35 million mobile units. Even if Japan and USA have a higher percentage of air-conditioned offices and houses than European countries, air conditioning units on this side of the Atlantic still lead to higher demand for peak electrical loads in summer. In future the search for a substitute for electrical power will be an important theme. Discussions at home and abroad about shutting down nuclear power stations or the threat of power cuts in summer due to overload from air conditioning systems are fuelling demand for alternatives.

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Absorption cooling is itself a tried and tested technology. What is new is its combination with a solar power system. The concept exploits the fact that the biggest need for keeping cool tends to be at the same time as when the solar gain is at its highest. The solar power system also helps to heat up water for domestic or industrial use. In the interim period and in winter the energy is also used to supplement the central heating system. This means the degree of effective use of a solar collector over the year can be improved considerably. At the same time it provides an elegant solution to the problem of overheating that always occurs with bigger systems in particular.

These systems are basically suited to all service buildings fitted with air conditioning, such as hotels, shopping malls, offices, computer centres or hospitals. Solar-powered cooling should already be an alternative worth considering for all environmentally aware companies and institutions. Constantly rising electricity prices and the ongoing standardisation of technology will make these leading-edge systems attractive to more building contractors in future. The market potential is enormous, especially in countries with a lot of sunshine or those where electricity is very expensive.

Christian Hilgenberg, CEO of *IEM Ingenieurbüro Energie- und Messtechnik AG*

2.2 Cost trends

Cost trends and type of use

An initial assessment of the market incentive programme shows that the costs for users of a complete solar collector system in Germany have fallen by 10% overall during the last three years. At the same time heat generation costs have been reduced from 22 to around 19 €Cents/kWh. 75% of systems were installed to heat water (5-7 m^2) and 25% were combination systems for providing hot water and heating (9-12 m^2).

2.3 Major players

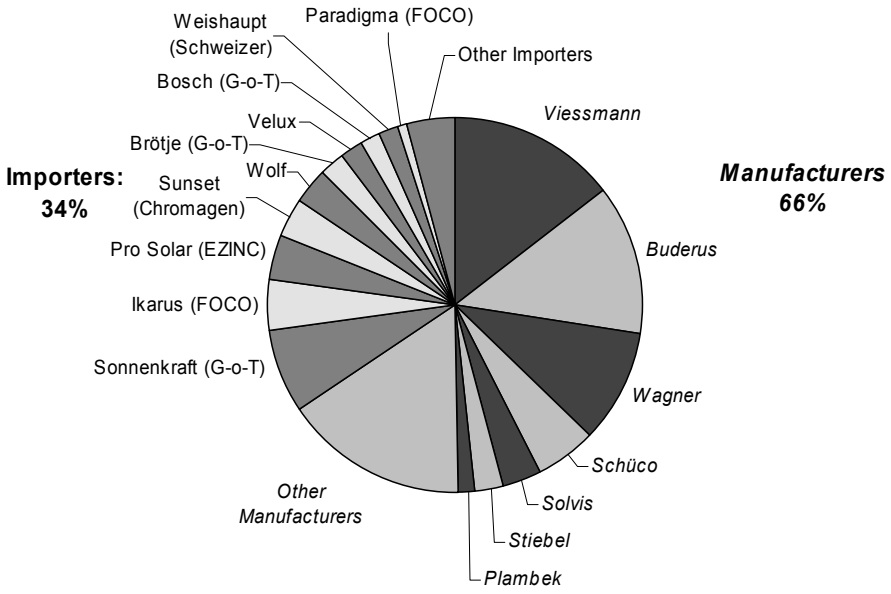
Global solar thermal power industry is very fragmented

The global solar collector industry is very heterogeneous and has many small players. It is extremely difficult to obtain specific company information on players in this line of business, and a comprehensive overview is practically impossible. Instead we simply provide details of the German market and its players by way of example. In 2003 domestic manufacturers accounted for 66% of Germany's flat-panel collector market, and foreign manufacturers 33%.

Strong fluctuations in market shares

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*. Fig. 13 provides an overview of the most important players in Germany's flat-panel collector market in 2003.

Fig. 13: Market shares of manufacturers and providers of flat-panel collectors in Germany in 2003 (total 655,000 m²). OEMs shown in brackets *(G-o-T: GreenOneTec)*



Basic data: W.B. Koldehoff, April 2004

Difficult situation in solar thermal power

In Germany the more attractive overall conditions for photovoltaics seem to have made solar thermal power less popular with owner-occupiers. Companies are becoming increasingly concerned because solar thermal power is growing more slowly than they would like. After collapsing in 2002, the industry experienced strong growth last year but has still not regained the level of 2001. Forecasts for 2004 and the following year are also rather gloomy, unless measures are taken soon, such as the *Regenerative Heat Law* (RegWG), which is currently being drafted and takes its cue from the existing Renewable Energy Law.

Figures for 2004 are uncertain

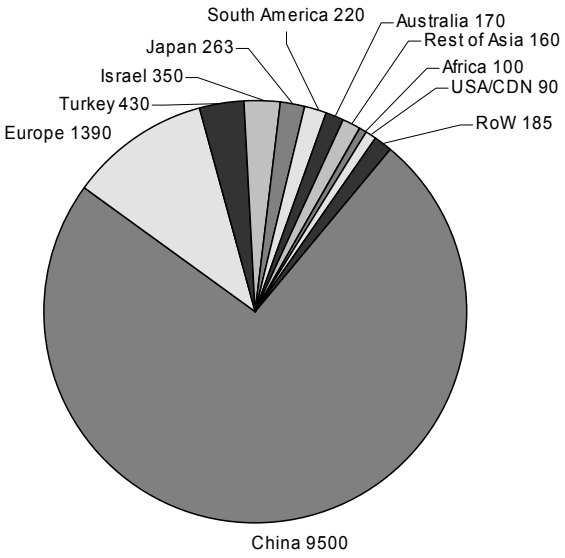
The difficult market environment is certainly one of the reasons why individual companies were unable or unwilling to give figures for their annual production in 2004 at the time of going to press. For a long time the industry hoped that order intake would still rise before the end of the year, and was therefore reluctant to give guidance on full-year figures despite repeated questioning.

2.4 Major global markets

There are huge differences between national markets in terms of newly installed collector area. China, easily the world's biggest market, continues to enjoy dynamic growth and sets the global growth rate. Global newly installed area came to around 12.9 million m^2 in 2003, about 23% more than 2002. Around 75% of this area was installed in China. Apart from China, other important markets include Germany, Greece, Austria and also Turkey, Israel and Japan. Compared with last year's report we have provided more details on the individual countries in Fig. 14. The size of the solar collector market varies a lot from one

continent to another. Asia and Europe are the leaders, although other areas would appear to be at more of an advantage because they get more sun.

Fig. 14: Newly installed collector area (1000 m^2) in 2003 (all types), broken down into the most important markets. Total newly installed area was around 12.9 million m^2, 23% up on 2002

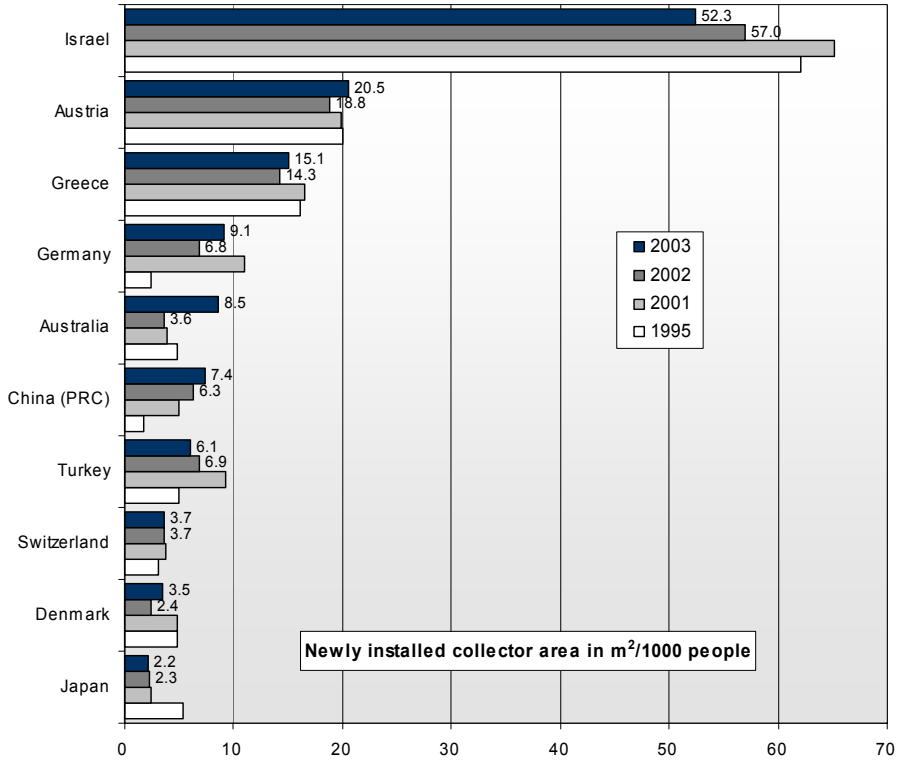


Basic data: W.B. Koldehoff, October 2004

Top ten solar collector countries: Germany, China and Australia overtake Turkey

China's dominance in terms of newly installed area is mainly due to the huge size of its population. If we compare the area installed per head of population, i.e. "newly installed collector area p.a. per 1,000 inhabitants" (Fig. 15), then Israel is undisputed leader when it comes to per capita installed area. But this figure has been steadily declining in Israel since 2001. It is interesting to note that of the 400,000 m^2 installed area, 350,000 m^2 was used to replace old systems and only 50,000 m^2 was genuine newly installed capacity. Austria's annual newly installed area is relatively constant, at around 20 m^2/1000 people, as is Greece with approx. 15 m^2/1000. Germany increased its newly installed area by 34% on 2002, overtaking Turkey in the process. The same applies to China, which was the only country to have consistently increased its per capita newly installed area for four years in succession. The Chinese market therefore seems to be showing little sign of saturation.

Fig. 15: Top ten countries – Market size per head of population: Newly installed collector area p.a. in recent years, in m^2 per 1,000 people



Source: W.B. Koldehoff, October 2004

Australia has an effective energy law

But last year it was Australia that made the biggest progress. Newly installed area more than doubled from 70,000 m^2 to 170,000 m^2 (from 3.6 to 8.5 m^2/1000 people). This growth is clearly attributable to the *Renewable Energy (Electricity) Act 2000* passed in April 200 but has had its first real impact this year.[5] This law foresees another 9,500 GWh electricity being generated from renewable energy sources by 2010, or fossil-fuel energy being replaced by renewables. If they make this substitution, power companies receive Renewable Energy Certificates (RECs) which can also be traded. Providers of solar collectors therefore see their system particularly as suitable replacements for the very common and energy-guzzling continuous-flow water heaters. What is attractive to end users is that solar collector manufacturers such as *Rheem/Solahart* can offer systems at a discount that is equivalent to the proceeds from the sale of the REC.

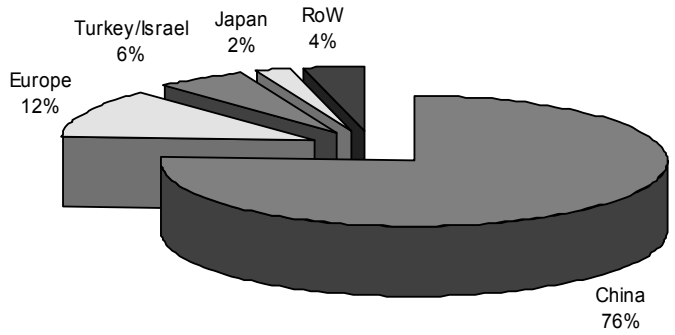
Lot of technical potential

The example of Australia, where newly installed area increased 250% last year, clearly shows that a sensible incentive programme can provide a valuable boost to an immature market. This is vital in order to tap the heat generating potential through solar collectors. One of the biggest hurdles is still the relatively high investment costs compared with conventional heating systems. Fig. 16 illustrates the collector area currently in operation in the individual countries and regions at

5 www.greenhouse.gov.au/markets/mret/index.html

the end of 2003. This area is 14.7% greater than in 2002. The geographical spread has stayed relatively stable. China is also top when it comes to collector area in operation. Its share has increased from 56% to 59%.

Fig. 16: Solar thermal systems in operation in 2003 shown by country (total glazed collector area: approx. 85.2 million m^2). Entire area in operation increased 14.7%



Source: W.B. Koldehoff, October 2004

2.4.1 China

China: Biggest market growing the fastest

With a share of almost 75% of collector area installed in 2003, China is the biggest solar thermal market, with a newly installed area of 9.5 million m^2 and a percentage increase of around 23%. The cumulative collector area at year-end 2003 was over 51 million m^2. 75% of these systems are installed in private houses for heating water, 20% are in communal facilities and 5% are used in industry. About 85% are flat-panel collectors and 15% vacuum tube collectors. There is trend towards higher quality flat-panel collectors with a 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. On the supply side there is still a huge number of small and medium-sized producers. As we reported last year, growth in China is even more astonishing given that the government provides no financial subsidies for installing systems, but only incentives 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 since China's booming industry is commandeering more and more of the limited energy supply.

China wants to increase its renewables quota to 10%

At the *Renewables 2004* conference in June in Bonn, China announced its intention to increase the quota of renewables as a percentage of total installed energy capacity to 10% by 2010. Solar thermal power can certainly benefit from this policy as well.

2.4.2 Japan

Japan's market in decline...

Last year in Japan around 98,000 m^2 of collector area was installed for systems with a storage tank and around 165,000 m^2 for thermosiphon systems. This represents a further decline in newly installed area of 27,000 m^2 compared with 2002. At year-end 2003 a total of around 7.35 million m^2 of collector area was in operation.

...but gets support

Things look brighter again for 2004, however, since the trend for residential systems is clearly moving upwards, from 2 m^2 collector area towards 3 m^2. The use of hot water and the demand for home comforts have clearly increased. In October 2004 the Japanese government decided to introduce a new incentive next year for solar collectors, with a subsidy of up to 50% of the installation costs for public buildings and up to 33% for private households. However, the government's target of a total 35 million m^2 collector area by 2010 will be very difficult to achieve. This would require annual growth of 25% in the years to come.

2.5 Market trends in Europe

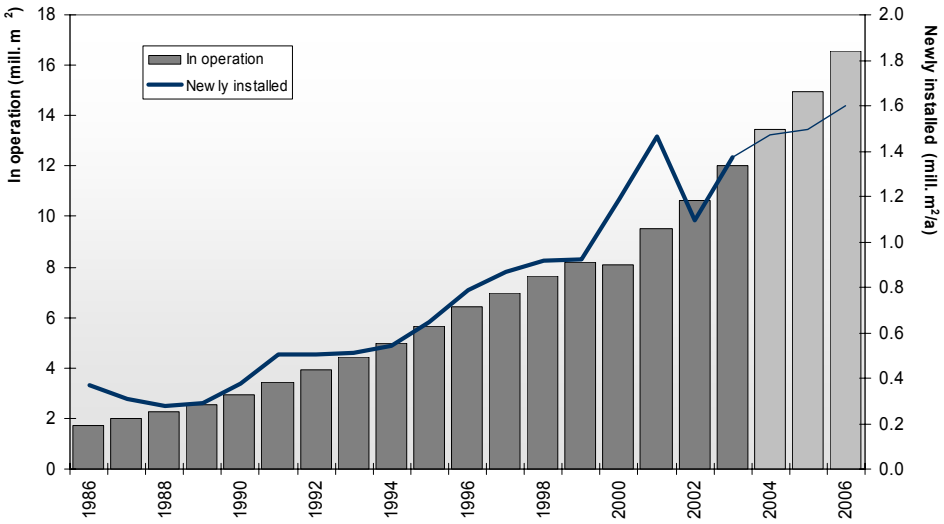
Growth in Europe's solar thermal power market has also been far from consistent in recent years. This is because of uncertainties surrounding incentive programmes in Europe's most important market, Germany. Because of this, and also due to intensifying competition from photovoltaics, it is difficult to make any precise short-term forecasts.

25% growth in installed solar collector area in 2003

According to figures published by ESTIF[6] in June 2004 for Europe[7] , newly installed area in 2003 rose 25% to 1.38 million m^2. Last year our forecast was 1.33 million m^2, which was a little too low. This year we predict 7% growth to 1.47 million m^2. Next year growth will only be 2% mainly because of the feared decline in newly installed area in Germany. In 2006 we then expect the newly installed area to rise again slightly to around 1.6 million m^2. This is equivalent to an annual growth rate of 5% over the next 3 years. Fig. 17 shows that this year's figure will only just reach the level of 2001 again, with a newly installed area of 1.47 million m^2. For more details on why growth is so sluggish, please see the chapters on the major markets (Germany, Greece and Austria).

6 ESTIF: European Solar Thermal Industry Federation, www.estif.org
7 EU 15 incl. Switzerland and Norway, excl. Luxembourg

Fig. 17: Development of installed (glazed) solar collector area in Europe. Sarasin's estimate for 2004 to 2006: 1.47, 1.5, and 1.6 million m² newly installed area



Source: ESTIF, June 2004; W.B. Koldehoff, October 2004 and own estimates

80% of products were sold in Germany, Greece and Austria

In Europe, sales of solar collectors are still concentrated in three countries: Germany, Greece and Austria. They account for some 80% of all products. While collector sales in Greece and Austria have stagnated in recent years, manufacturers in Germany have seen sales rocket after the market slump in 2002. Last year collector sales were up 39%. The rest of the newly installed area is split between the other countries, in very similar proportions as in 2002.

Table 1 provides an overview of the European solar collector market. Because growth rates have been so volatile in some cases during the last three years, it seems more sensible to present the total growth rates of individual countries over the entire three year period from 2000 to 2003 in the table. The total market expanded 17% over this period. The main trends were higher than average growth rates in Spain and France, as well in the UK, Belgium and Ireland – although the last three started from a very low base.

Table 1: Solar thermal power market in Europe 2003: Overview ordered by size of market share

Country:	Total in operation 2003 (m^2)[8]	Europ. market share (%)	Market development 2000-2003			2004 est. market newly install. area	2005 est. market newly install. area
			Installed 2000	Installed 2003	00-03 market growth		
Germany	4,898,000	41%	620,000	750,000	21%	780,000	700,000
Greece	2,779,200	23%	181,000	161,000	-11%	180,000	170,000
Austria	1,921,594	16%	152,944	165,200	8%	185,000	200,000
Spain	341,566	3%	40,487	80,000	98%	80,000	100,000
Italy	398,785	3%	45,249	53,000	17%	55,000	80,000
France (EU)	237,400	2%	23,500	42,000	79%	52,500	70,000
Denmark	299,890	2%	30,200	19,000	-37%	20,000	22,000
Switzerland	324,954	3%	26,500	26,800	1%	28,000	32,000
Netherlands	263,737	2%	27,660	33,000	19%	20,000	30,000
Portugal	160,640	1%	5,500	6,000	9%	7,000	9,000
Sweden	173,661	1%	19,117	18,000	-6%	25,000	30,000
UK	149,920	1%	11,850	22,000	86%	26,000	32,000
Belgium	35,874	0.3%	3,400	11,000	224%	10,000	16,000
Finland	10,030	0.1%	2,000	2,000	0%	2,000	3,000
Ireland	4,405	0.04%	400	600	50%	800	1,500
Total	**11,999,656**	**100%**	**1,189,807**	**1,389,600**	17%	**1,471,300**	**1,495,500**

Basic data: ESTIF, June 2004; W.B. Koldehoff, October 2004

2.5.1 Germany

Germany still European forerunner when it comes to solar thermal power...

Germany has extended its lead as Europe's biggest solar market, increasing its market share from 38% (4.2 million m^2) at y/e 2002 to 41% (4.9 million m^2) at y/e 2003. Last year it added another 750,000 $m^{2\ of}$ newly installed area. Germany's programme of incentives for renewable energies is a guiding light for the rest of the world. It is one of the main factors behind the success of the German market, with grants awarded of up around 10 to 15% of the investment sum. In 2002 and 2003 these financial incentives were worth approximately EUR 200m. About 70% of this amount was used for solar thermal systems. Since January 2004 the level of incentives has still been running at EUR 110 per m^2 of gross collector area (no repayment obligation), not only for private individuals and entrepreneurs, but also for public companies. The maximum subsidy per individual system is EUR 25,000 (status: Sept. 2003).[9] To be entitled to a government subsidy, the collectors must have a minimum output of 350 kWh per m^2 p.a. A current overview of the German government's and federal states' incentive programmes is provided by BSi.[10]

...but will growth slump again in 2004?

Based on demand experienced up to the middle of the year, it seems reasonable to hope that the newly installed area could climb above one million square

8 Definition of the term "in operation" was taken from the ESTIF report "Sun in Action II": systems installed up to 1989 have an average service life of 15 years, compared with 20 years for those installed after 1990.

9 Market incentive programme for renewables run by the Bundesamt für Wirtschaft und Ausfuhrkontrolle (BaFa)

10 www.bsi-solar.de/foerderprogramme.asp

metres for the first time. The nine-month deadline for December applications from 2003 has now passed and now it looks as if the year-end figure will actually only finish slightly up on last year, at 780,000 m^2. It seems that a substantial portion of approved applications were never actually realised. The new applications received in the first half of the year also reveal a not particularly encouraging picture. According to details from the *Bundesamt für Wirtschaft und Ausfuhrkontrolle* (Bafa) the number of applications in the first nine months was about 45% down on last year. In 2005 we even expect the market to drop more than 10% to around 700,000 m^2 of newly installed area.
This can mainly be explained by the overall economic situation in Germany, bad customer advice and poor marketing, and the more attractive subsidies provided for photovoltaics. Many customers basically want to install a solar system on their roof, but because of limited budgets at present decide on the cheapest and more attractive option.

Overshadowed by photovoltaics

At the moment photovoltaics seems to have the better image and a higher media presence than solar thermal power. The unspoken question is: Why does photovoltaics attract so much more money and attention than solar thermal energy? For without any subsidies, solar thermal power is more economical than grid-connected photovoltaics. As far as climate protection is concerned, solar thermal power certainly deserves more support, since specialist publications show that an operational solar collector avoids (measured by area) well over twice as much CO_2 as an equivalent PV system. Another fact is that Germany, like the rest of Europe, consumes less electricity than energy for heating and cooling. But as far as producers of solar thermal power are concerned, the public debate focuses far too much on electricity generation.

A heating law modelled on the EEG

Gradually the solar thermal energy industry is realising that it has to do far more in the way of PR work, marketing and distribution, and wants to remedy this shortcoming in future. Furthermore it is not yet clear what the incentive will be in the coming year. As already mentioned, associations of solar thermal energy producers are drafting a proposal for a Regenerative Heat Law (RegWG) to make solar thermal subsidies less dependent on state support. As with the EEG, a tax would be levied on conventional fossil fuels such as oil and gas, which could then be used to pay a bonus for producing heat from renewable sources. But consideration is also being given to a building ordinance requiring thermal solar systems to be installed in new single and multiple occupancy homes. But it will take at least a couple of years until such rules can provide fresh stimulus for Germany's solar thermal market.

2.5.2 Greece

Stagnation in the coming years

Escalating electricity prices in the mid-seventies in Greece were the main trigger for the development of a highly successful solar thermal energy market, which has since become a little saturated, however. The reason for the increasing saturation is on the one hand the cumulative collector area – 260 m^2/1,000 population, the second highest after Israel – and also the stagnation in the amount of newly installed area during the last four years. In 2003 there was 161,000 m^2 of newly installed area and this year the figure will be around 180,000 m^2. Our forecast for 2005 is about 170,000 m^2 due to two conflicting trends: On the one hand the government wants to provide a certain amount of support, in the form of lower VAT, to kick-start the market again. At the moment the rate of VAT charged on solar systems is 18%, compared with 8% for electricity and gas. On the other, construction activity is expected to ease off now that the Olympic Games are over. Fresh stimulus for growth could at best come from the promotion of solar-assisted cooling systems. Greece's *FOCO* is a major European player, and exports more than half its production to Germany.

2.5.3 Austria

Austria is becoming a major exporter of solar collectors

In 2003 around 407,000 m^2 of newly installed area was produced in Austria, compared with 328,000 m^2 in 2002.[11] This is equivalent to a year-on-year increase of 24%. In 2003 as much as 59% of the collectors produced in Austria were exported, compared with 52% in 2002. So Austria's export quota is steadily increasing. The domestic newly installed area in 2003 came to 165,000 m^2, an increase of 8% on 2002. About 9,300 new solar systems were installed for hot water and ancillary space heating, and 300 solar systems for heating swimming pools. At the end of 2003 a total of 1.92 million m^2 collectors were in operation. Subsidies in Austria vary enormously from one federal state to the next. Average subsidies for a solar system for supplementary heating (20 m^2 collector area, 1,500 litre storage tank) are around EUR 4,900.

Future trends

Over the period 1990 to 2000 the average annual growth in the solar thermal power market was around 15%. The mood was very upbeat in the Austrian market in the first half of 2004, as confirmed by a survey of leading solar companies by the industry association Austria Solar. The latest forecast for full-year growth is 10%-12% (185,000 m^2). September saw the start of a four-year solar thermal energy programme designed to increase the amount of installed collector area to around 200,000 m^2 p.a. by 2008. If this manages to kick-start the market, Austria should have almost 4 million m^2 collector area installed by 2010 and an additional 3,000 jobs could be created (compared to 2000).

11 Solar market in Austria 2003, Austria Solar, www.austriasolar.at

2.5.4 Switzerland

Solar thermal power market: Trend reversal in sight?

Last year a total collector area of 26,820 m^2 was sold in Switzerland. This figure is made up of own production, plus imports and minus exports.[12] The majority (98%) was flat-panel collectors. These figures are the highest ever, with the exception of 1998. It is difficult to tell yet whether this marks a trend reversal, because the growth rate is so low. The newly launched "Go for solar" (solarbegeistert) programme still doesn't seem to have made much of an impact after twelve months. But its effect is meant to be long term, and therefore extends over a period of three years. Experience also shows that in most cases well over a year passes between the contractor's initial request and the installation of the system. The weak state of the construction industry is another reason why the low rate of growth can actually be seen in a positive light.

2.5.5 Other markets

Big potential: France, Italy and Spain

Over the last three years France's collector market has grown at a very dynamic rate of 180%, but this was starting from a very low level. The other two hopefuls – Italy and Spain – are not taking off as quickly as expected and are still far below their potential. Even so, ESTIF forecasts even higher growth for Spain in the years to come. This is because some Spanish cities and local authorities have passed building regulations requiring solar heating systems to be installed when building or renovating properties ("Barcelona model").

Rising oil and gas prices in the USA make solar collectors more attractive

In the USA solar collectors, or chiefly unglazed black tube systems, have been used exclusively for heating swimming pools. As oil and gas prices continue to soar, more interest is now being paid to combine solar-powered hot water and heating systems. Higher oil and gas prices mean shorter payback periods for solar systems. In addition, many federal states have set up incentive programmes for both thermal and PV solar systems.

2.6 Market trends up to 2020

China continues to grow

In the last five years China has developed into a dynamic and self-sustaining market. In 2003 the newly installed area was 16.5% higher than in 2002. This growth is in line with the government's planned growth of 17% p.a. up to 2015. Demand for solar collectors will continue to rise in future as the Chinese economy continues to flourish. Given the government's projects in the area of renewables, we therefore expect the positive trend to continue in China.

New markets slowly being added

It is likely that new markets will emerge in future in countries that have not had much solar thermal power previously, but which do have favourable climatic conditions. These include southern European countries, Australia and above all newly industrialised countries such as India, Indonesia and Mexico, and not forgetting the USA as well.

12 Solar, Swiss Solar Energy Association, market survey 2003

A more active policy is required to achieve the EU target of 100 million m^2 in 2010

The EU's policy sees solar thermal energy generation as an important pillar of future heat supply from renewable sources. The European Commission's White Paper sets a target of 100 million m^2 for collector area in operation in 2010. This corresponds to about 260 m^2 per 1,000 people. Greece has already achieved this target, and Austria will also achieve it before 2010. But other countries are a long way off it. Real EU growth rates in the past (CAGR 1994 -2003: 9.2%) are much lower than those needed to meet this target. Even if improved overall political conditions allow growth rates of over 35% to be achieved (comparable with growth in the wind power industry until recently), it would still mean the target would not be reached before 2015.

EREC growth targets for the EU-15

The latest figures published by the EREC forecast annual growth rates of 23% for solar thermal energy up to 2020. This estimate is based above all on the large unexploited potential. This would mean a total collector area of over 200 million m^2 in operation in 2020.

Sarasin sees growth only taking off in Europe from 2006 onwards

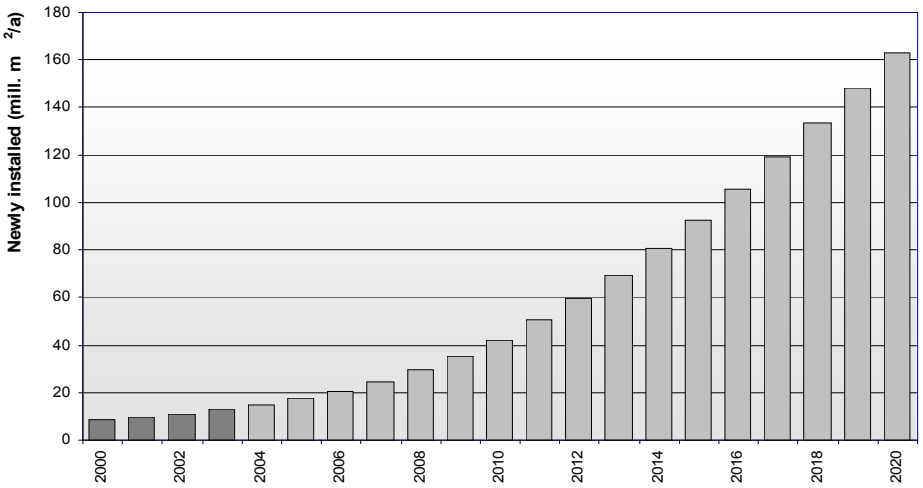
In Europe the industry is likely to stagnate in 2004 and 2005 following its slump in 2002 (-22%) and rapid recovery in 2003. Up to 2006 we only expect disappointing average growth of 5% p.a. Newly installed area is expected to climb again after that, helped by extensive legislative and political support in a number of countries, escalating oil and gas prices and new fields of application (see Table 1, page 37).

Average global growth 16% p.a. from 2003 to 2020

Our forecast for global newly installed area in 2003 was 12.5 million m^2, 3% below the actual installed area of 12.9 million m^2. This was an increase of 23% on 2002. For the current year we are expecting a global newly installed area of around 15 million m^2, an increase of 16%, mainly thanks to the ongoing boom in China but also in various other non-European countries. These regions will prevent growth from slumping too much due to the two-year lull in Europe. The growth rate should settle around 17-20% up to 2010. At the end of this decade around 250 million m^2 of collector area will therefore be in operation. In 2010 we expect newly installed area to grow by around 42 million m^2.

Because of a tendency for market saturation, we expect growth rates to gradually fall between 2011 and 2020, to just 10%. This is equivalent to a CAGR of 16% in newly installed area over the entire period 2003-2020. The global market for newly installed solar collectors would therefore have a volume of around 160 million m^2 in 2020 (Fig. 18).

Fig. 18: Sarasin forecast for global solar collector market. Newly installed area in m^2 p.a.



Solar thermal power's contribution underestimated and...

So far the global contribution made by thermal solar systems for hot water and space heating has been heavily underestimated. According to IEA statistics (Solar Heating Worldwide 2001), the productive global solar collector area of approx. 85 million m^2 contributes approximately 40,000 GWh to the annual heat supply for hot water and space heating. In terms of energy production, solar thermal energy is therefore more prominent than wind power, which has notched up major successes worldwide in the last ten years.

... large potential still untapped

Even so, only a small portion of the energy generated for the heating market comes from solar power. According to a forecast by international solar experts, half the world's hot water requirements could be met from solar energy, and a quarter of its heating needs. In the case of heating for industrial processes up to 150° C, such as car washing or pasteurisation, solar systems could also supply a quarter of energy requirements. In the case of air conditioning for buildings, one of the fastest growing markets in the world, solar energy would also be capable of meeting a substantial percentage of the energy requirements. Particularly with these low-temperature applications, it makes a lot of sense both from a technological and economic viewpoint to substitute oil and natural gas with solar power, particularly in response to the growing energy demand in southern Europe and newly industrialised countries. Further research and development is required in order to exploit this enormous potential. Solar thermal energy for heating water is already a mature technology, although there is still room for optimisation in the area of compact storage tanks and room heating systems.

But at the same time solar thermal energy still needs support in the form of public subsidy programmes or suitable legislation, such as the Spanish building regulations already mentioned (Barcelona model) or the Regenerative Heat Law planned in Germany. In order to achieve a maximum impact, these initiatives

must be introduced across a broad front in many different countries. It remains to be seen whether this will actually happen within a useful time frame.

Postscript: New conversion factor for solar thermal power: 0.7 kW_{th}/m^2

According to the latest press release from ESTIF, the IEA SHC Programme[13] and the leading associations of the solar thermal power industry agreed an important innovation at their last meeting: In future solar thermal power is to be expressed in terms of thermal energy (kW_{th}) rather than in square metres of installed collector area, as has been the custom. Experts agreed on a conversion factor of 0.7 kW_{th}/m^2. A detailed description of the conversion factor can be found on the IEA SHC website.[14]

This change makes it far easier to compare solar energy with other forms of renewable energy. It also shows, for the first time, just how important solar thermal energy actually is. Based on the square metre figures for globally installed glazed collector area, the cumulative capacity up to the end of 2003 comes to around 60 GW_{th} (0.7 x 85.2 million m^2) Solar thermal energy is therefore more important than wind energy (2003: 40 GW_{el}) and well ahead of PV (2003, OECD countries: 1.8 GW_{el}).

13 International Energy Agency Solar Heating and Cooling Programme
14 www.iea-shc.org

3 Solar thermal power plants

3.1 Fields of application

Concentrating Solar Power (CSP)

A solar thermal power plant usually generates electricity using steam turbines. The steam is produced with the help of solar energy. The "conventional" part of the power plant (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 plants combined with conventional plants or with a storage system

Solar thermal power plants 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). In terms of output, these systems are currently the only solar technology that can replace traditional power plants fired by fossil or nuclear fuels.

Apart from pure solar systems, hybrid systems are also planned that are integrated into conventional power plants (e.g. gas and steam) and are responsible for generating some of the steam during daylight hours, thereby saving on fossil fuels.

On the other hand 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 additional income to be earned from selling expensive peak load current. These systems can achieve peak efficiency rates of over 20% when converting solar irradiation into net current fed into the mains grid, and not just at selected times, but throughout the day.

Other fields of application: Decentralised generation of electricity and heat

Apart from centralised generation of electricity, smaller decentralised power plants based on parabolic dish technology can be used, for example, to replace diesel generators. Decentralised systems exclusively for generating heat for industrial processes are also possible with solar thermal technologies.

Please refer to our 2003 report for a detailed description of the technologies used. In what follows we limit our comments to a progress report on the various projects.

3.2 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 German-Spanish test centre, *Plataforma Solar de Almeria*. Nine SEGS power plants, financed purely with private money and based on parabolic dish technology, were built 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 run today on a commercial basis and so far have contributed almost 50% of the world's total solar electricity generation.

Deregulation brought major changes to the electricity sector, and the focus shifted from building new power stations to expanding sales markets. Furthermore, not many people thought it likely that the global energy industry would continue to be burdened by persistently high oil prices.

Now the situation has fundamentally changed due to technological progress and a more favourable political and economic environment in some cases, such as climate change protocols, further oil price hikes and incentive programmes for renewables. Recently there has been a real shift towards new power station projects.

Global Market Initiative for solar thermal power plants (CSP GMI)

The international governmental conference *renewables2004* in Bonn was an important platform for the expansion of solar thermal power plants. At this year's conference the Global Market Initiative (CSP GMI) was presented, whose purpose is to encourage the construction of solar thermal power plants in the sun belt. The aim is to install total capacity of 5,000 MW by 2015, thereby bringing the technology to market maturity in order to make it fully competitive with power stations running on fossil fuels and without having to offer additional incentives in the form of payments for feeding solar power into the mains grid. The partners in this initiative include the *European Solar Thermal Power Industry Association (ESTIA)*, *SolarPACES* (a joint venture between the *IEA* in Spain and *U.S. Solar Energy Industries Association (SEIA))* and the *Global Environmental Facility (GEF)* of the World Bank, UNEP, Germany's Ministry of the Environment and the Reconstruction Loan Bank (KfW). Any government from countries in the sun belt is eligible to take part in this initiative, as well as those countries that have special industrial know-how in the area of solar thermal power plants.

The agreement contains a series of measures that include:

- Suitable legislation and incentive programmes to encourage electricity generated from renewable sources to be fed into the mains grid,
- Transnational or intercontinental trading of electricity, with more attractive payments for renewable energy,
- CO_2 certificates and bi- and multi-lateral financing programmes.

New projects take off...

After a dry period lasting over a decade when no new projects were implemented, several projects are now about to start as 2004 comes to an end. The number of these projects and their finance volume do suggest that they are set to make a more sustained impact in the reference markets of sun belt countries.

The current renaissance of solar thermal power plants is attributable to the consistent energy and environmental policy of a number of industrialised nations that have gradually developed regulations to provide clear financial incentives for renewable energies. Spain and Germany lead the way here with their renewable energies laws, followed by some of the US federal states, which are now introducing more strictly defined renewable portfolio standards. The success of wind power in the wake of the renewable energies law – Spain has around 6 GW interfaced to its grid, Germany about 14 GW – was an incentive to try and repeat this with electricity generated from solar thermal power plants, especially since it can be generated in a very controllable way, thereby making the mains grid more stable.

Most of the activity in the project development and construction of solar thermal power plants has therefore been concentrated in Spain and in the sunny southwest region of the USA. At the end of this year, preparations will start for the construction of the 10 MW_{el} Solar Tower Project PS 10 of the Andalucian contractor *Abengoa* and the 50 MW_{el} Parabolic dish Project AndaSol 1, a team project by the technology specialist *Solar Millennium AG* and the Madrid construction company *ACS/Cobra*. The total amount invested in these two projects is over EUR 300 million.

But more importantly, Spain's attractive tariffs for electricity fed into the mains grid from solar thermal power stations (18 €cent/kWh – in addition to the pool price of the Spanish Electricity Trading Market) have encouraged a number of follow-on projects, some of which have already been approved. Iberdrola is preparing 5 parabolic dish projects (50 MW_{el} each), while *Solar Millennium/ACS/Cobra* have another three 50 MW_{el} projects in the pipeline. We can assume that one of these projects will be completed every year, so that 100 MW_{el} solar thermal capacity is added each year. In the next five years around EUR 0.5 billion p.a. will be available in project financing.

In the USA, the foundation stone is about to be laid for the 50 MW_{el} Eldorado project of *Solargenix* (parabolic dish), while in New Mexico a tender is being prepared for a 50 - 100 MW_{el} parabolic dish project for the start of 2005. In California tenders are expected to go out for projects worth several 100 MW_{el} over the course of next year.

If we include the solar thermal ISCC hybrid projects in Egypt, India and Morocco, which are co-financed by *Global Environment Facility (GEF)* and for which tenders have already been published, the annual investment volume worldwide is expected to be over EUR 1 billion.

Rainer Aringhoff, General Manager *Solar Millennium AG* & General Secretary *European Solar Thermal Power Industry Association (ESTIA)*

Dr. Michael Geyer, Executive Secretary *IEA SolarPACES*

Table 2: overview of projects in the field of solar thermal power plants

Location	Financing	Solar technology	Engineering, supplier	Hybrid operation [a)]	Solar capacity (MWel)	Total capacity (MWel)	Project status [b)]	Due to come on stream
1) Algeria	Algerian EEG / loan issued after bid selection	Parabolic dish	Bid Selection	Yes CCPP	25	150	3	2007
2) Australia	Partly from Australian Green-house Gas surcharge	Updraft	SBP/EnviroMission	No	200	200	2	n/a
3) Egypt	GEF/World Bank	Parabolic dish	Selection after prequalification, RfP & Bid Selection	Yes CCPP	30	135	3	2007
4) India	MNES, GEF; KfW	Parabolic dish	Fichtner Solar (consultant of Indian EVU and KfW)	Yes CCPP	35	120-160	2	2007
5) Iran	Decided depending on project structure / IPDO	Parabolic dish	Fichtner Solar and Flabeg Solar (Consultants of IPDO)	Yes CCPP	70	300-400	3	n/a
6) Israel	Israeli technology programme + banks	Parabolic dish	Solel as promotor / selection procedure not yet defined	Yes, but high solar quota	100	100	3	n/a
7) Italy	Italian research programme	Parabolic dish (with molten salts)	ENEA (national energy research centre) industry and Enel as users	Yes CCPP	40	500	2	2006
8) Jordan	Decided depending on project structure	Parabolic dish	Pre-screening by Solar Millennium; RfP & Bid Selection	Yes; steam or CCPP	30 - 130	130	3	n/a
9) Crete	Greek EEG & renewable energy efficiency programmes	Parabolic dish	THESEUS A.E. (Solar Millennium, OADYK, Fichtner)	No	50	50	2-3	2007±
10) Morocco	GEF/WB/O.N.E.	Parabolic dish	F/S by Pilkington Solar & INITEC; RfP & Bid Selection	Yes CCPP	30	220	2	2007
11) Mexico	GEF/WB/CFE	Parabolic dish	F/S by Spencer Management; Bid running since 2002	Yes CCPP	30	300	2	2007+
12) Spain, AndaSol 1 - 3	Spanish EEG + project financing	Parabolic dish	Solar Millennium + ACS Cobra	Yes; with approx 90% solar quota	3 x 50	3 x 50	2	1st plant: 2006
13) Spain, PS10	Spanish EEG + project financing	Tower	Inabensa/Solucar	Yes; with approx 90% solar quota	10	10	2	2005/6
14) Spain, Solar Tres	Spanish EEG + project financing	Tower	SENER / Solar Tres	Yes; with approx 90% solar quota	15	15	3	n/a
15) Spain, Euro SEGS	Spanish EEG + project financing	Parabolic dish	EHN / Solargenix	Yes; with approx 90% solar quota	15	15	3	n/a
16) Spain	Spanish EEG + project financing	Parabolic dish	Iberdrola	Yes; with approx 90% solar quota	5 x 50	5 x 50	3-4	n/a
17) S. Africa	Not known	Tower	ESKOM	No	100	100	3	n/a
18) USA, Nevada	PPA with Nevada Power / project financing	Parabolic dish	Solargenix	Yes, with 25% fossil fuel supp.	50	50	2	2006

a) CCPP: combined cycle power plant
b) Project status: 1 = under construction; 2 = in planning phase; 3 = pre-planning phase (feasability test); 4 = intended projects

3.3 Market outlook

On the brink of commercialisation

The projects listed in Table 2 show that solar thermal power plant technology is about to take a leap from the development phase into commercial use. Overall we think the opportunities for this solar technology are very good in the long term. 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, Middle and Far East, India, Australia. This potential is evident from the state of technology already achieved and the improved overall conditions for this type of plant:

- The cost competitiveness of these technologies, i.e. comparable costs to conventional power station technology, 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 working with 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“.

Risks

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.

Conclusion: Prospects are still intact

The future of solar thermal power plant technologies is heavily dependent on the success of projects currently in the planning stage. If they 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. As described earlier, the CSP GMI envisages the creation of new solar thermal capacities of around 5,000 MW by 2015. Given the current status of projects the target of 5,000 MW by 2015 seems ambitious, but not altogether impossible. As Table 2 shows, about 3,000 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.

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