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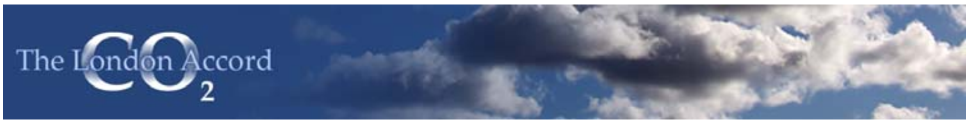

Solar Energy 2007

The industry continues to boom

Extract from the Sarasin Solar Energy study 2007
prepared for the London Accord project

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Please see important information on last page

Sustainable Investment

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Executive Summary

PV industry continues to boom

Solar cell production jumped another 44% in 2006, from 1740 MWp to more than 2500 MWp. Production capacities are being expanded at all levels of the value chain – especially solar-grade silicon – allowing more rapid growth for the entire PV industry. Capacities for the individual components seem to be growing more harmoniously than in the past. Cooperation between companies, or their vertical integration, has intensified. The increases announced in the production capacity of solar-grade silicon are mainly destined for direct delivery to individual customers with long-term supply contracts. The spot price will therefore only fall slowly, once additional quantities of solar-grade silicon come on to the market from 2009 onwards.

Installed PV capacity climbed 17% to 1650 MWp in 2006

Newly installed global PV capacity was approximately 1650 MWp in 2006. This is equivalent to 17% growth on last year (2005: 1400 MWp). As a result of the discrepancy between capacity expansion and installed capacity, the PV industry is therefore changing from a market driven by demand to one driven by supply. Surprisingly, however, prices have remained relatively stable and show some elasticity in adapting to the relevant incentive conditions. The attractive markets at the moment are Spain, Italy, the US and Korea. But in future, governments will regularly review the subsidy programmes to make sure they are commensurate, and reduce excessive reimbursement levels. Politicians are aware that the costs for photovoltaics have dropped in response to new technological developments and cheaper silicon.

Thin-film modules set to increase their market share to over 20% by 2010

Things are moving in the **thin-film technologies** industry. In 2006 the production capacity for thin-film modules amounted to 200 MWp, equivalent to a market share of 7.8% (2005: 5.8%). Recent months have seen a sharp increase in new and existing activities in this field. There are now over 80 companies active in thin-film technology. This sector will enjoy disproportionately high rates of growth up to 2010, inflating its market share to over 20% in the process.

8.25 GWp new PV capacity to be installed by 2010

A number of hurdles, including the bottleneck in the silicon supply and the lack of incentive programmes, now seem to have been cleared for the **future development** of the global PV market, allowing the boom to continue. We have therefore increased our forecast and now expect newly installed PV capacity to reach around **8.25 GWp** by 2010. This corresponds to an average annual growth rate of 50% over the period 2006–2010. For the next decade (2011-2020) average annual growth is expected to run at well over 22%.

Solar collectors could become competitive before long

With **oil and gas prices still high**, solar thermal energy has attracted far more public attention and has automatically become more appealing in terms of cost. The solar thermal plants being installed today now deliver about 8 times as much energy as photovoltaic systems.

Newly installed solar thermal capacity up 24% in 2006

Some 24% more **solar collectors were installed** in 2006 than in 2005, reaching 17.0 GW_{th} worldwide. Around 74% of these were installed in China, so that the Chinese market increased by 20%. However, China's energy supplies remain scarce and expensive. Given this backdrop, solar-powered hot water supply for households (90% of the market) is a competitive technology even without state subsidies.

Booming European solar thermal market grows 45% in 2006

Europe's solar thermal power market has also developed well, growing by 45% in 2006. Europe is dominated by six countries: Germany, Austria, Greece, Italy, Spain and France, which have a combined market share of 87%. Germany, Europe's biggest market, grew by 55%, but even the Swiss market – which is small in absolute terms – expanded 33%. Solar thermal power is becoming increasingly financially attractive for owner-occupiers in particular, in view of rising oil and gas prices.

Growth predicted at 26% for 2007

For the current year 2007 we predict that newly installed collector capacity worldwide will reach around 23 GW_{th}, which is 26% more than last year. Up to 2010 we forecast European growth rates of over 20%, and around 25% worldwide. This growth is being driven mainly by the dynamic performance of China and other developing countries. In 2010 we therefore predict a market volume (newly installed capacity) of 42 GW_{th}, with roughly 214 GW_{th} on stream worldwide. With the increasing maturity of the market, we expect average growth will then ease back in the following decade (2011- 2020) to around 18% p.a. The global market for newly installed solar collectors would thus reach a volume of approximately 236 GW_{th} in 2020.

Solar cooling is ready to take off

Air conditioning based on solar thermal power is still an important growth factor for the future, but at the moment does not command a relevant market share. On the other hand, solar-powered combined systems for producing hot water and as a booster system for space heating currently play an important role.

CSP with slow start…

The growth of **concentrating solar power (CSP)** is not currently as dynamic as solar collectors and photovoltaics. Plans for new CSP power stations have now assumed more concrete shape thanks to technological progress and more favourable political and economic conditions (such as climate protection agreements, high oil and gas prices, subsidies for renewable energies and generous feed-in tariffs). In Spain and the western USA in particular, the incentives to encourage CSP systems have improved significantly.

…but new plants under construction

There are currently **seven CSP power station projects** under construction around the world. Two of these were connected to the grid this year. These are the first new CSP power stations to be built since the nineties. These large-scale projects take a long time to secure the necessary planning consents and obtain funding.

CSP plants with 2.5 GW capacity in 2010

Future development relies heavily on the success and experiences of these projects (in terms of cost efficiency and the reliability of the technology). The **growth potential** seems to be substantial, but these projects do seem to require a longer start-up phase. As far as costs are concerned, CSP systems are positioned between the cheaper solar thermal technology and more expensive photovoltaics. Given the projects in the planning phase, we think CSP power stations with a total capacity of 2.5 GW_{el} could be built by 2010 and 16 GW_{el} by 2020.

20% CO_2 abatement through solar energy in 2030

With climate change at the top of the agenda, the question of the **CO_2 abatement potential** and the associated prevention costs of the individual solar energy technologies is becoming increasingly relevant. Although this potential may be relatively small at present, our estimates show that solar energy could make a significant contribution to reducing CO_2 emissions up to 2030. Overall it would help to avoid around 3.0 Gt CO_2 of the extra emissions of 14 Gt CO_2 envisaged in the reference scenario of the International Energy Agency (IEA). The bulk of this comes from heat generated by solar collectors (50%), and the rest from photovoltaics (39%) and CSP power stations (11%).

Solar energy still expensive, but will become a feasible CO_2-abatement strategy soon

CO_2 abatement costs for all solar technologies are currently much higher than the prices at which CO_2 certificates are being traded (20 - 40 EUR/t). Photovoltaics is currently still a very expensive strategy for reducing CO_2, costing 328 EUR/t CO_2. But the costs are lower for solar thermal power (104 EUR/t) and CSP (115 EUR/t). The cost-saving potential for all three energies is enormous, however. In 2018 first solar thermal power, then photovoltaics (2021) and CSP (2025) will no longer incur any CO_2 abatement costs.

Introduction

Focus is on the entire spectrum of solar energy use

This is the fourth year we have published a study on the entire solar energy market, covering all aspects from photovoltaics through to solar collectors and CSP power stations, and each year the report gains more substance. Our goal is to draw the attention of the general public and the financial community to solar energy as a whole. We are confident that attractive investment opportunities will soon emerge in solar thermal power as well.

Report concentrates on key PV industry themes

This year's solar energy report examines the following key themes for the PV industry: the supply of polysilicon, price and demand trends, the expansion of thin-film technology and the internationalisation of markets.

Country trends and long-term market forecasts

Our regional survey of the three biggest national PV markets – Germany, Japan and the US – is rounded off by a brief description of emerging markets such as Spain, Italy, India and China. As usual, we look at trends in the individual PV markets and include Sarasin's long-term forecast.

How well are PV companies equipped to deal with future challenges?

Once again we provide an analysis of the strategic positioning of the leading PV companies, which we presented for the first time in last year's report, supplemented by ten new companies. This is not intended as a buy or sell recommendation, but simply offers an assessment of the companies at a strategic level, going forward.

CO_2 abatement costs: a key indicator in climate policy

This year's report includes a new chapter on climate change and the problem of CO_2 emissions. The fact that solar energy is carbon neutral is an important plus point. We compare the costs of CO_2 abatement for each of the solar technologies and examine the reduction potential up to 2030. The energy payback period for the individual technologies has now fallen dramatically and only lies somewhere between 1 and 3.5 years, which is much less than a system's estimated service life of 20 to 25 years.

Solar collector chapter reviews national markets

Our chapter on solar collectors provides a description of the most important markets such as China, Germany, Greece and Austria. We also provide a short-term forecast for the European solar thermal energy market up to 2010. Our long-term forecast shows global trends in solar thermal power up to 2020.

CSP power stations: two new plants about to come on stream

Concentrating solar power (CSP) now appears to be moving into a crucial phase. New plants are about to come on stream in Spain and the US. This chapter provides an update on all the global projects currently under way.

Photovoltaics (PV)

Growth continues apace in 2006

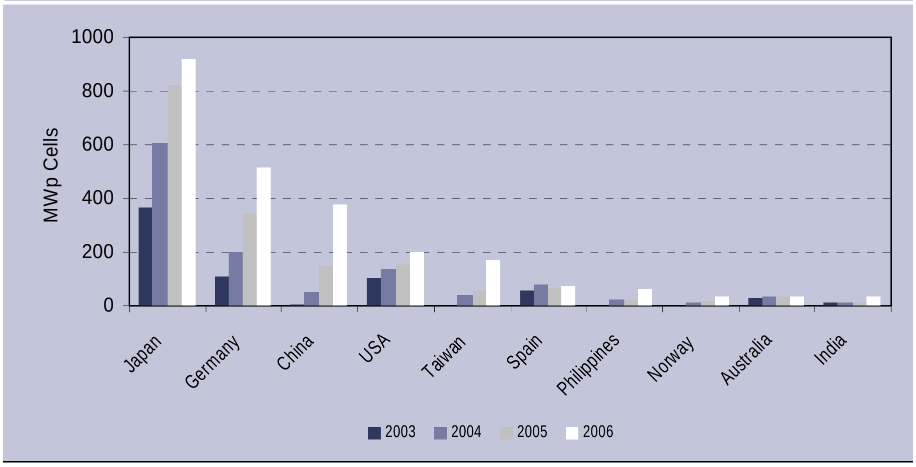
PV cell production once again rose more than 40% in 2006

In 2006 global solar cell production increased from 1740 MWp[1] to more than 2500 MWp. This is equivalent to a growth rate of around 44%. Apart from increasing production capacities, this was achieved through more efficient use of materials at all stages of the value chain. Among other things, the amount of waste produced when cutting and sawing wafers continues to drop, and wafers are becoming increasingly thinner. Fracture rates have also been reduced through optimal machine setup. The average amount of solar-grade silicon used per MWp last year was roughly 10.2 t, compared with 11 t in 2005. New material-saving technologies, such as 'string-ribbon' and 'edge-defined film growth' were developed further as well. The efficiency ratio is continuing to move steadily towards 20%, while some cell types have already passed this mark. Finally, the high prices for solar-grade silicon have encouraged additional material to be channelled from the chip industry into photovoltaics applications.

Solar cell production in IEA-PVPS countries increased 27%...

According to the latest figures from IEA PVPS[2] , global solar cell production in PVPS countries alone jumped from 1500 MW in 2005 to 1905 MW in 2006, equivalent to growth of 27% (prior year: 35%). Japan is still the world's biggest producer, with an annual output of 920 MWp (12% growth). Production also rose sharply at cell manufacturers in Korea (18 MWp annual output; +240%), Norway (37MWp; +85%) and Germany (514 MWp; +50%).

Fig. 1. Country breakdown: the world's top 10 solar cell producers



Source: IEA-PVPS and Sarasin, 2007

... while production in non-PVPS countries jumped by more than 110%

In 2006, non-PVPS countries produced 2006 cells with a capacity of around 520 MWp, representing an increase of 112% on 2005 and significantly faster growth than in IEA-PVPS countries. The figure of 520 MW now corresponds to

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1 Megawatt Peak: Unit of measurement for the maximum potential output of PV modules. Measured under standard test conditions (STC).

2 Trends in Photovoltaic Applications; Survey Report of selected IEA countries between 1992 and 2006. IEA Photovoltaic Power Systems Programme – Task 1; September 2007. All other IEA-PVPS references concern this publication. www.iea-pvps.org

roughly 20% of total global cell production of 2525 MWp (Fig. 1). Cell production has also risen sharply in Taiwan (170 MWp annual output; +183%), the Philippines (62 MWp; +170%) and China (380 MWp; +153%). Having grown so rapidly, China has now knocked the US from third place in the world rankings.

Key themes for the future development of the PV industry

Future challenges for the solar industry?

What are the key themes and challenges facing the solar industry in the years ahead? In this section we look at the silicon supply, price and demand trends and developments in thin-film technology.

Silicon supply

Will the ambitious plans to expand polysilicon production close the supply gap?

Over the past three years, the supply of polysilicon has fallen well short of the demand from solar cell producers, and this has inevitably had repercussions on the price of polysilicon. Long-term delivery contracts for polysilicon – if they are still being agreed at all – are around EUR 40-50 per kilo of solar-grade silicon, while prices on the spot market are more than EUR 200 per kilo. Opinions differ within the PV industry as to when this raw material gap will eventually be closed. The fact is that we are still hearing about plans for the expansion of existing silicon production, or the building of new production facilities. The leading manufacturers alone (*Hemlock, MEMC, Mitsubishi, REC, Sumitomo, Tokuyama* and *Wacker*) will have combined production capacities of over 80,000 t by 2010 (current figure: 38,000 t p.a.). There are also another 30 companies with plans that could boost total silicon capacities to more than 130,000 t by 2010. Our forecasts are based on the likelihood that only some of these capacities will be implemented according to schedule. Delays are particularly likely in the Russian and Chinese projects, and with other newcomers who do not have the necessary technological know-how.

The cost of making polysilicon may well come down

Many expansion plans are based on the well-established but energy-intensive Siemens process, which requires approximately 80 - 130 kWh of electricity per kilo of end product. To achieve a decisive cut in production costs, other production processes such as fluidised bed reactors (FBR) (20 - 40 kWh/kg) and metallurgical preparation (10 - 20 kWh/kg) of silicon are required. The lower energy consumption of these last two processes will be a decisive cost reduction factor in future for the entire solar industry.

Is the quality of metallurgical silicon good enough?

At the moment it is still unclear how quickly this “impure” metallurgical silicon will be adopted by the PV industry. Industrial-scale experience with this material has to be acquired first, especially regarding its use in highly efficient solar cells and their long-term behaviour. Many wafer and cell producers need to use standardised raw materials. These companies will first have to perform extensive tests on the new material before it can be fully integrated into their manufacturing processes. The first step in this direction will be to mix metallurgical silicon with conventional purer solar-grade silicon.

More generous quantities of solar-grade silicon should become available from 2008 onwards

Fig. 2 shows the development of the available supplies of solar-grade silicon, together with the reduced silicon requirement per MWp of output and the resulting potential crystalline-silicon (c-Si) cell production.

Fig. 2: Production of polysilicon and solar-grade silicon and maximum c-Si cell production

Solar-grade silicon and solar cell production	2006	2007e	2008e	2009e	2010e
Total polysilicon production	**35'700**	**42'400**	**59'500**	**85'200**	**101'000**
Silicon quantities available for PV industry (incl. destocking and recycling)	23'500	27'000	35'800	59'300	79'300
Growth vs. prior year	**6'500**	**3'500**	**8'800**	**23'500**	**20'000**
annual growth rate of solar-grade silicon	**38%**	**15%**	**33%**	**66%**	**34%**
Silicon requirement per MWp (t)	**10.2**	**9.6**	**9.0**	**8.6**	**8.2**
Potential c-Si solar cell production	**2'300**	**2'800**	**4'000**	**6'900**	**9'700**
Annual growth rate of c-Si cell production	**49%**	**22%**	**41%**	**73%**	**40%**

Source: individual companies, Sarasin 2007

The amount of silicon available in 2007 should be roughly 15% higher than 2006. Taking into account the material savings along the entire value chain, the potential crystalline cell production could rise by 22%, to approximately 2800 MWp. In 2008 and 2009 substantial quantities of extra silicon (+33%, and +66% respectively) will then come onto the market and should ease the bottleneck. With the new raw materials available, crystalline solar cell production could therefore increase by as much as 41% to roughly 4000 MWp in 2008, and by 73% to 6900 MWp in 2009. Our forecast shows that solar-grade silicon should be in sufficient supply on the market from 2009 onwards. After that we will then have a clearer picture as to whether the announced plans for expanding solar-grade silicon production have been implemented according to schedule, encouraging further growth in the PV industry in the process.

Cell and module producers will have surplus capacity

The more even balance between silicon supply and demand will lead to lower spot prices as well from 2009 onwards. We also believe that the current expansion plans for solar cell capacities are extremely ambitious given future demand predictions. New cell producers would do well to the hedge a large proportion of their sales, otherwise they run the risk of their production capacities being underutilised.

Price and demand trends

Module price index registers only slightly weaker prices

The Solarbuzz module price index has surprisingly only dipped slightly in recent months, in both the US and Europe. The average price in the US is around USD 4.80/Wp and in Europe about EUR 4.78/Wp.[3] Business is also booming in PV installations. In September 2007 the lowest price for a multi-crystalline solar module was USD 3.00/Wp from an American dealer. The cheapest monocrystalline module costs EUR 3.14, also in America. The lowest price for a thin-film module was EUR 2.55 from a European dealer.

Demand increases in response to rising capacities and attractive feed-in tariffs

Production capacities are now being significantly expanded at all levels of the value chain. Large quantities of solar modules will therefore come on to the market in the years ahead. This will put downward pressure on the price of both cells and modules.

Far more attention is now being focused on demand and prices. How flexibly will demand respond to changing end consumer prices? Given the current tariffs for

[3] www.solarbuzz.com/moduleprices

renewable energy fed into the mains grid in Germany and other major markets, the return on a PV installation can be calculated fairly accurately, so that a massive collapse in prices seems unlikely. As soon as prices correlate again with the tariffs charged for renewable energy fed into the mains grid, and returns of 6 - 8% are possible, demand will pick up again. Today's PV industry is a global market, i.e. cells and modules finish up wherever the price is highest, or where the best margins can be earned.

Lower feed-in tariffs lead to tumbling prices

But the subsidies for renewable energy will not continue indefinitely. The intended policy is to gradually reduce incentives created for solar energy, giving free rein to market mechanisms again. The lower subsidies paid will therefore exert more pressure on prices, until photovoltaics eventually achieves parity with mains grid electricity, as planned. As soon as production costs for solar energy and peakload power for end consumers reach the same level, photovoltaics will become an economically viable alternative. In California, where peakload power easily costs EUR 0.18 - 0.30/kWh, this breakeven point should be reached as early as 2010 or so.

Thin-film modules expand their market share

Thin-film technologies increase their market share

With solar-grade silicon in such short supply, far more attention has been focused on thin-film technologies. In 2006, total thin-film module production amounted to around 200 MWp, equivalent to 7.8% of the global market (2005: 5.8%). Modules made of amorphous silicon (aSi) accounted for the lion's share, at 4.8%, followed by cadmium telluride (CdTe) at 2.8% and copper indium diselenide (CIS) at 0.2%.

Thin-film modules have attractive properties

Solar cells based on thin-film technologies have a lot of potential. Nowadays they are already capable of achieving efficiencies of up to 17%. The advantages offered by this technology include low raw material consumption, the use of only small quantities of solar-grade silicon (or none at all), a superior temperature coefficient (i.e. consistent performance at higher temperatures), new areas of application through the use of flexible materials and a shorter energy payback time since the manufacturing process is less energy-intensive. At the same time thin-film technology offers substantial cost-cutting potential. In addition to expanding production capacities, the goal is to cut costs over the long run to one euro per Wp and to increase cell efficiency to as much as 25%. Thanks to all these advantages, we expect thin-film modules to expand their market share more quickly than average.

Ambitious plans regarding capacities, costs and efficiency

At present more than 80 companies are producing thin-film solar cells and modules worldwide. In the past year alone, 24 new companies have moved into this technology. In this industry there are a number of big players with many years of experience and expanding production capacities. There are also a handful of newcomers, a small number of which have the potential to develop into significant players. Many of these companies are 'pure players', but a lot of companies already established in silicon technology are also attempting to enter the thin-film technology market. Many manufacturers see the expansion of their thin-film activities as a type of hedging of their existing technology portfolio, while others are dedicated solely to this technology .

Above-average growth

In view of its ambitious capacity expansion plans, thin-film technology will enjoy higher than average growth in the years ahead. We expect this technology to increase its percentage of total module production from 8% at present to around 23% in 2010, or approximately 2000 MWp.

Low production costs

Cadmium telluride (CdTe) currently boasts the lowest production costs of all the thin-film technologies. Amorphous silicon (a-Si) technology is only slightly behind this, costing around USD 1.50/W. There is still a lot of cost reduction potential to be achieved through enhanced processes, driven especially by big equipment manufacturers. The lowest production costs have been achieved by CIGS Technologie with its roll-to-roll process, superior efficiency and thin, flexible substrates.

It is still very difficult to provide forecasts for the different thin-film technologies because of their immaturity and unforeseeable hurdles in the expansion of production capacities. Even so, it is worth continuing to monitor this young industry very closely and not to underestimate its dynamism.

Market development and outlook

The most important national markets

Germany

High prices depress demand

Last year Germany installed 953 MWp of new PV capacity (official figures from the Ministry of the Environment, BMU). This is equivalent to a growth rate of 10% compared to the revised 2005 figure (866 MWp). Growth rates therefore fell for the second consecutive year and are now lower than the global growth rate of 17%. In Germany, demand depends to a significant extent on the returns that can be earned on bigger installations. Since system prices did not keep pace with the digression in the feed-in tariff last year, potential returns – and subsequently demand – sank.

EEG: a huge success story

At the start of July, the Ministry of the Environment gave a positive assessment of the Renewable Energy Act (EEG). With the help of the EEG, German manufacturers have become global leaders in the area of renewable energies, particularly solar energy. According to a BMU status report, the overall economic benefit of the EEG already exceeds its original costs.

EEG review results in slightly higher degression rate as of 2009

But the structure of the subsidies in individual areas is to be adjusted in a bid to improve efficiency and create additional incentives for innovation. With the pending EEG renewal, the suggestion is to increase the digression of the amount reimbursed for renewable energy fed into the mains grid by two percentage points for photovoltaics from 2009 onwards, to 7% for roof-mounted installations and 8.5% for free-standing systems in open spaces. The industry appears to be able to live with these higher degression rates. In addition, the financial market had already anticipated such an increase, and share prices barely responded to the announcement of the planned change in feed-in tariffs.

German market picking up again: 25% annual growth up to 2010

In 2007 we expect the market to pick up again after a temporary subdued period, and forecast around 1300 MWp newly installed capacity. We expect the average annual growth rate to exceed 25% in the period up to 2010.

Japan

Japanese market going through a tough patch without state subsidies

In 2006 Japan's newly installed PV capacity dipped slightly for the first time to 287 MWp (2005: 290 MWp). This was down to the expiry of Japan's most important subsidy program, the "Residential PV System Dissemination Programme" (RPVDP) in October 2005. So far the government has not announced any follow-up program with a similar remit. The market for residential systems (around 90% of total sales) is now more or less open to free market mechanisms. Many house builders are pushing the sale of finished houses with a PV system fitted as standard. This makes the purchase of a PV system relatively straightforward, especially in the case of new-builds. But there are also plans to install more PV systems on apartment blocks. Since 1992, Japan's electricity suppliers have already been refunding surplus solar energy at mains grid electricity prices (net energy bill). Japan has comparatively high electricity prices which continue to soar. Combined with low interest rates, this could in future make an investment in a PV system seem attractive even without subsidies. Japanese law also requires energy providers to use renewable energies to cover a certain proportion of their electricity sales (Renewable Portfolio Standard, RPS). Many different ministries are also increasingly supporting promotional and training programmes for solar energy. Although the Ministry of Economy, Trade and Industry (METI) does not have any other subsidy plans in the pipeline, it is standing by its target of achieving a cumulative PV capacity of 4.8 GWp by 2010. We expect the growth rate to reach 9% in 2007. The Japanese market will then enjoy annual growth rates of 34% in the period up to 2010.

USA

Energy security and climate change are important election issues

Renewable energies are currently a hot topic in the US. President Bush wants to drastically reduce America's dependence on foreign energy supplies. His Energy Initiative[4] aims to promote the various renewable energy technologies. In addition, the themes of securing the energy supply and tackling climate change are top of the agenda in the forthcoming election campaign. The Solar America Initiative (SAI) announced by the President seeks to achieve an installed PV capacity of 5-10 GWp by 2015. A total of 20 federal states have now defined targets for the quota of renewable energies in their energy portfolio (RPS) and launched their own incentive programs.[5] As in Japan, more and more new buildings are now coming on to the market with PV systems fitted as standard. The prospects in this market segment have deteriorated, however, due to the current US housing crisis.

California still leads the way

California is still the dominant market in the US. In 2006 two-thirds of grid-connected PV systems were installed in this state. The solar energy incentive program approved by the Californian Public Utilities Commission (PUC) is channelling approximately USD 3.2 billion into the expansion of solar energy use over the next 10 years. By 2019, one million buildings will be fitted with solar roofs with a total capacity of 3000 MWp. Home owners and com-

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4 www.whitehouse.gov/stateoftheunion/2006/energy/energy_booklet.pdf

5 www.dsireusa.org: Database of State Incentives for Renewable Energy

panies receive discounts if they convert to solar energy.

Growth expected to accelerate

In 2006 newly installed capacity in the US amounted to 145 MWp. This represents an increase of 41% on 2005. In view of the incentive programs and continuously rising energy prices, we expect growth to accelerate by 80% or 260 MWp of newly installed capacity in 2007, and by 80% or 470 MWp in 2008.

America's PV market offers significant potential in the long run, since many regions enjoy abundant sunshine, and the country also has to cope with energy consumption peaks in the summer, which leads to supply bottlenecks and extremely high prices for peakload power. This makes PV systems more attractive from a cost perspective as well, compared with other countries.

Spain (60 MWp newly installed capacity in 2006)

Plenty of sun and generous financial incentives – will the government increase the threshold

There appear to be no signs of mounting price pressure in Spain, unlike Germany. On the contrary, Spain is currently in the grip of solar fever. Levels of sunshine and the tariffs for renewable energy fed into the mains grid are both high. Demand is therefore booming, and we anticipate a flourishing PV market in the years ahead. There are two reasons for Spain's PV boom: initial investments in solar power have been much lower than in other renewable energies, such as wind. The current rates paid for renewable energy fed into the mains grid guarantee a return of 8-12% over 25 years. This means that PV providers can also demand higher prices than in Germany, without undermining demand. In 2006 the size of the market trebled to 61 MWp (2005: 20 MWp). The total number of registered projects has already reached the government's target of installed PV capacity of 400 MWp. The responsible minister wants to raise the threshold swiftly to 1200 MWp, while at the same time cutting the feed-in tariff.

Demand high, despite ambivalent government stance

The appealing conditions have already attracted more than 400 companies from other sectors into the PV market. A number of established PV players fear that these new opportunistic companies – without any significant experience or customer service – could damage the reputation of the industry as a whole.

The Spanish Association for Renewable Energies (APPA) is concerned that the government might view the boom in photovoltaics as overheating and may therefore reconsider the terms of its incentives. This is causing uncertainty in the industry, as it is still highly dependent on government subsidies.

In view of the dynamic pace of market growth at present, our forecast for Spain is more than 1400 MWp of newly installed capacity in 2010, which is equivalent to an average annual growth rate of roughly 120%.

Italy (12.5 MWp newly installed capacity in 2006)

Italy's Renewable Energy Act starting to show an effect

Italy is growing into one of Europe's most important solar energy markets. After a rather feeble 12.5 MWp last year, newly installed capacity is expected to reach more than 100 MWp in the current year. In the meantime, the Italian government is also pinning high hopes on the future growth of the national solar power industry. The obstacles we described in last year's report, such as administrative barriers, the complicated subsidy system and the poor availability of solar modules, seem to have been gradually overcome. We therefore expect market volume to reach 500 MWp newly installed capacity by 2010. This is equivalent to an average annual growth rate of 150% between 2006 and 2010.

India (5 MWp newly installed capacity in 2006)

India's growth slow but steady

With a cumulative capacity of approximately 90 MWp, India still leads the rankings for the developing countries. Unfortunately its growth rate cannot keep pace with the Mediterranean countries. Most of the applications in India are off grid and are being used for the electrification of rural villages. In 2006, a total of 60,000 households were fitted with solar-powered lighting. The government's target is 280 MWp of cumulative capacity by 2012, including solar thermal installations.

China (15 MWp newly installed capacity in 2006)

Chinese government backing renewable energies

With a cumulative PV capacity of 85 MWp at the end of 2006, China is starting to turn more towards renewable energies in a bid to satisfy its soaring energy requirements. By 2010, as much as 10% of its electricity needs are to be met by renewables. The important role that photovoltaics plays in China's energy policy is confirmed by the growth targets, incentive programs and associated government investments. One of the priorities here is the electrification of rural regions. Investments of EUR 5-6 billion have been earmarked for this purpose up to 2015. China's PV market will therefore be initially dominated by off-grid applications, but will be supplemented in the long run by grid-connected installations.

PV industry has ambitious expansion plans and high export rates

The Chinese PV industry has ambitious expansion plans, reflected in the creation of substantial production capacities along the entire value chain. With the advantages it enjoys by virtue of its location, i.e. low energy and labour costs, China will continue to expand its module production especially, and will play an important role in this sector. Chinese companies have fewer competitive advantages when it comes to polysilicon and cell production. New Chinese companies still face production costs in the region of EUR 35-40/kg in polysilicon manufacture, while experienced European and American producers can get by with just EUR 15-20/kg. Cell production is capital intensive. Its production costs are driven by high degrees of cell efficiency, which can only be achieved with ample know-how. Given the annual additional volume in the domestic market of "only" 15 MWp, the expansion plans of the Chinese PV industry in the coming years suggest that the business will remain heavily geared towards exports.

Development of PV markets up to 2020

1646 MWp new capacity installed in 2006 (+17%)

In 2006 newly installed PV capacity worldwide amounted to 1646 MWp. This is equivalent to a 17% increase on last year's revised figures. This year's total will be approximately 2750 MWp, equivalent to a growth rate of 60%. As in last year's report, our long-term forecast shows the development in the annual **newly installed PV capacity worldwide.** We have based our forecast on the market estimates for the most important countries. The historical data are based mainly on information from IEA-PVPS.

8.25 GWp new PV capacity to be installed by 2010

After relatively subdued growth in 2006, large quantities of solar-grade silicon came onto the market again in 2007 and the availability of all the intermediate products, up to the finished modules, improved significantly. The supply bottleneck in the solar-grade silicon market will therefore ease both this year and next.

For 2010 we forecast around 8.25 GW of newly installed PV capacity worldwide (Fig. 3). This corresponds to an average annual growth rate of 50% for the period 2006-2010.

Fig. 3: Sarasin forecast for national PV markets (average annual newly installed capacity in MWp)

	Newly installed						CAGR
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**06-10**
Germany	866	953	1'300	1'625	1'983	2'320	25%
Italy	7	12.5	105	184	322	498	151%
Spain	20	61	450	698	1'046	1'465	122%
Rest of Europe	48	94	150	218	337	455	48%
Europe	**940**	**1'121**	**2'005**	**2'724**	**3'687**	**4'738**	43%
USA	**103**	**145**	**261**	**470**	**846**	**1'480**	79%
China	**12**	**15**	**26**	**43**	**78**	**149**	77%
India	**8**	**9**	**17**	**31**	**57**	**106**	85%
Japan	**290**	**287**	**312**	**464**	**673**	**943**	35%
Rest of Asia	**20**	**25**	**49**	**96**	**180**	**38**	92%
Asia	**330**	**336**	**403**	**635**	**989**	**1'535**	46%
Rest of World	**35**	**45**	**78**	**146**	**270**	**503**	83%
Total new installation	**1'408**	**1'646**	**2'748**	**3'974**	**5'792**	**8'255**	50%
Annual growth rate	31%	17%	67%	45%	46%	43%	

Source: IEA-PVPS figures up to 2006, Sarasin estimates from 2007 onwards

New important markets emerging

Of all the national markets, Germany is still the heavyweight with a 58% share of the global market in 2006. It is followed by a number of new important markets such as Italy, Spain, Portugal and the US. In the Asian region, China, India, South Korea, Taiwan and Thailand are set to become the most important PV markets.

Off-grid systems becoming more important

In the long term, new markets of the future will start to emerge in developing countries in the area of off-grid applications. In these regions some two billion people have no access to mains electricity. Small decentralised solar home systems (SHS) or PV hybrid systems for supplying electricity to villages are often the quickest and cheapest way to substantially improve the living standards of predominantly rural populations. Not just PV cell and module manufacturers, but the entire business of solar systems technology stands to benefit from this huge sales market.

Key risks for the PV market

Based on the key themes outlined previously, the following factors present risks that could be a drag on predicted market growth in the mid-term:

- **Delay in expanding silicon capacities.** The expansion of production capacities does not proceed as planned, but is only implemented partially or with a delay. As a result, the shortage of silicon could drag on into 2008.
- **Changes in government subsidy programs**. The dependency on a handful of individual markets where photovoltaics are heavily reliant on government subsidy programs is still too great in the coming 4-5 years, until parity with mains grid electricity is achieved.
  - In Germany, the review of the EEG scheduled for 2008 and the announcement of an increase in the rate of degression for feed-in rates could act as a drag on market growth.

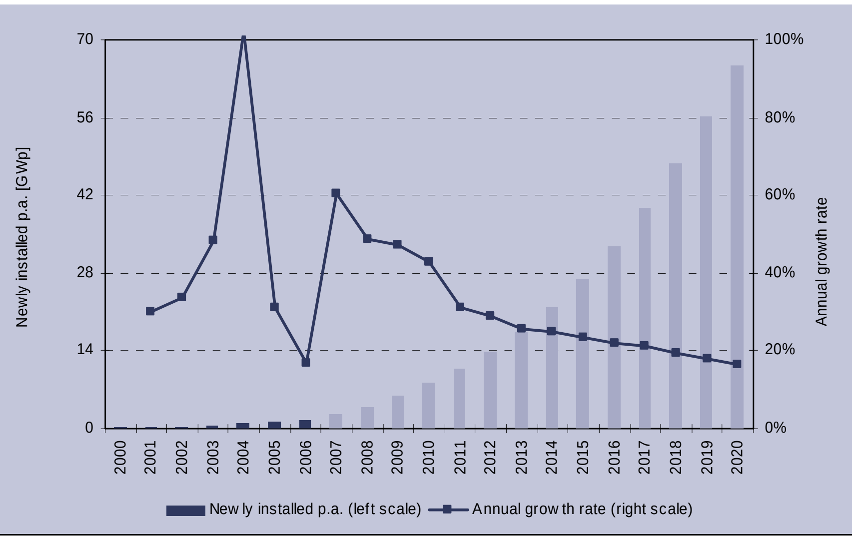
– Onerous bureaucratic hurdles or the capping of subsidy programs in Mediterranean countries will dilute their impact.
– Uncertain development in Japan: It's still unclear whether this market is developed enough to be able to continue to grow without subsidy programs.
– How will the Chinese domestic market develop? Will the government improve the incentive terms so that a national market can be created for China's booming solar industry?

- **Higher interest rates**. Credit-financed investments in PV systems are less profitable and the expected return for system operators is less attractive than fixed-interest investments.
- **US housing crisis**. Because of the crisis in the housing and mortgage markets, home owners do not seem particularly interested in investing in a solar energy system.
- **Increasing competition** from the industry's own camp through alternative solar energy technologies such as solar thermal power stations or other renewable energies (for example, farmers who invest in biogas or solar heating systems rather than installing a PV system).

Drive towards more self-sufficient energy supply will create upside potential

On the other hand, dwindling oil reserves and generally higher oil prices have helped to create additional potential for solar energy. There has been a marked increase in governments' willingness to promote renewable energies through incentives such as feed-in payments or tax breaks. The new priority cited by politicians is the goal of achieving more energy independence. Renewable energies, and photovoltaics especially, can make a contribution here thanks to their decentralised nature.

Fig. 4: Sarasin's long-term forecast for the global PV market



Source: Bank Sarasin, 2007

Climate debate and CO_2 abatement strategies

The current climate debate also provides an additional tailwind for the solar energy industry. Carbon-neutral energy generation is therefore becoming increasingly important. Potential quantities and price therefore play a pivotal role as part of a comprehensive strategy for preventing greenhouse gas emissions. This is examined in more detail in a later chapter.

In rural areas, a PV system can replace or supplement diesel generators. Here the price of oil has a direct influence on demand for PV systems. This market is limited mainly to the US and developing countries, and is only of secondary importance compared with the currently dominant grid-connected applications. This market segment could receive an additional boost from future allowances of CO_2 certificates.

Conclusion: steady growth in excess of 20% possible in the long run

In the longer term, therefore, the opportunities afforded by photovoltaics are still far from being exhausted. The balance between raw material production and demand seems to be gradually improving. In addition, economies of scale and advances in manufacturing technology (bigger units, automation), as well as new technologies and processes, allow costs to be cut significantly. Furthermore, certain applications in the field of thin-film technologies will soon make a breakthrough and their low-cost processes will enable them to capture specific market shares. All this should create an environment in which the current rate of growth can continue. According to this scenario, the annual installed capacity will therefore increase almost eightfold, from 8.25 GW in 2010 to around 65 GW in 2020. (Fig. 4). This is equivalent to an average annual growth rate of 22% in the second decade (2011-2020).

Strategic positioning of PV companies

Who has best long-term position? Consolidation inevitable

From a financial market perspective, expectations in the industry continue to be very high. These can certainly be fulfilled in the long run, but it is questionable whether all companies will make the grade. We anticipate a certain amount of consolidation in the industry going forward. The companies that will win through here will be those that are best equipped to deal with the industry's most important strategic challenges.

Reconciling supply and demand

The importance of the silicon supply bottleneck which dominated growth in 2005 and 2006 will significantly fade over the next few years. It is unclear at the moment exactly how this will affect prices.

One crucial factor over the long term, however, is the ability to keep costs permanently low in order to remain competitive. The main factors here are:

- **Solar-grade silicon – Spot market vs. long-term supply contracts.** Falling silicon prices as the capacity bottleneck eases could be beneficial to the entire PV industry. However, if prices do not fall to the same extent as in other parts of the value chain, cell producers will benefit from existing long-term supply contracts. If silicon prices drop quickly and sharply, however, these long-term agreements could turn out to be a burden.

- **Scale of production**. Because of the relative capital intensity, production costs are closely correlated with the scale of production. In this respect, smaller companies have a more difficult time than large firms.

- **Individual cost advantages**. In addition, each company enjoys certain advantages or disadvantages specific to their location, such as low labour costs or government subsidies.

- **Specialisation vs. vertical integration.** Companies that control several stages of the value chain have more flexibility to reduce prices than non-integrated companies. On the other hand, specialists can profit directly from favourable conditions on the procurement market.

- **Battle for market share – who has the most stamina?** Companies able to survive a period with lower margins should be able to acquire market shares in the mid-term. Producers from emerging markets, such as China, often tend to be willing to sacrifice margins in order to gain market share.

Assessment criteria

Given the factors described, we can identify the following criteria for a successful PV company. We believe the more a company can actively and positively embrace these qualities, the better its chances of becoming a successful player in the PV industry in the long run. Companies were assessed against the following four criteria using a scoring system ranging from 1 (small/poor) to 10 (big/good):

Reliable supply of raw material

The mid-term restrictions on the raw material side can be countered in various ways:

- Successful procurement management through contractual securing of the necessary quantities whilst maintaining consistently high quality,
- Development of own silicon supplies through joint ventures, participating interests or own production facilities,
- Introduction of silicon-saving improvements in production and product design of the crystal technology,
- Set-up or expansion of companies' own thin-film activities.

Late entrants are usually in a weaker position to secure their material requirements, as they have no track record and lack negotiating strength.

Company's critical mass

At every stage of the value chain (wafers, cells and modules), economies of scale play a vital role in reducing production costs. Only those companies whose cost structures are some of the best in the industry will manage to continue to achieve attractive returns. We also think it likely that suppliers in the pre-production phase will in future focus more on long-term partnerships with bigger, financially strong clients in a bid to minimise the default risk. This also applies to the growing number of large-scale projects throughout the world. Here too, leading suppliers have an advantage.

Technical know-how

Apart from size, companies also need to be able to differentiate their products from the competition through excellent products or production processes. On the one hand this is possible by using innovative technology such as highly efficient solar cells, employing production processes that save silicon or applying know-how in thin-film technology. On the other hand, the company can also acquire a technical edge by acquiring many years of experience along the entire value chain.

International customer base

The relative importance of Germany – traditionally the biggest PV market – will probably decline following the plan to increase the degression rate for feed-in tariffs, and grow less rapidly than the global photovoltaics market. A number of new, rapidly growing markets will emerge in the years ahead. In future the more lucrative markets will be in Southern Europe, Asia and North America. Establishing a presence in these markets early on is an important prerequisite for securing a place among the long-term industry winners.

Solar collectors

Overview

The second part of our solar report examines the active use of solar heat using solar collectors, in other words the generation of heat from the sun's thermal radiation.

High energy prices provide strong tailwind...

For thermal solar energy use, the costs of fossil alternatives (usually heating oil or natural gas) are an even more important factor than for photovoltaics. This economic substitution mechanism is already showing the first measurable results, since oil and gas prices have been stuck at extremely high levels for sometime – and are likely to remain there in the long run.

...and additional incentive mechanisms

Another supportive factor is that more and more governments are promoting solar heat through financial incentives or through new legislation. New EU targets, for example, stipulate that renewables should account for 20% of total energy consumption by 2020. The latest market developments reflect the favourable overall conditions.

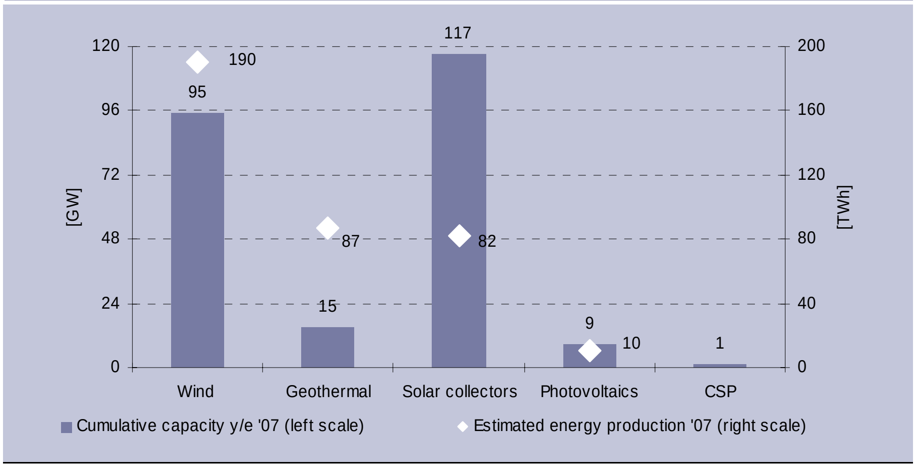
Solar thermal systems already very cost efficient

The heat generation costs for solar thermal systems are very attractive compared with oil- and gas-fired forms of heating. The slightly more expensive acquisition cost is quickly offset by lower fuel costs. Heat generation costs continue to fall and should become competitive from around 2018 onwards.

Contribution from solar collectors makes it one of the top tree renewables

Compared with other renewables (ignoring hydro power), power supplied from solar collectors comes in third place worldwide, behind wind and geothermal power. Roof-mounted solar collector systems are already supplying 50 million households worldwide with hot water. This energy contribution is by far the biggest of all the solar technologies (see the chapter on CO_2 abatement through solar energy).

Fig. 5: Cumulative capacity (GW) at y/e 2007 and energy generated in 2007 (TWh)



Source: Sarasin estimates, 2007

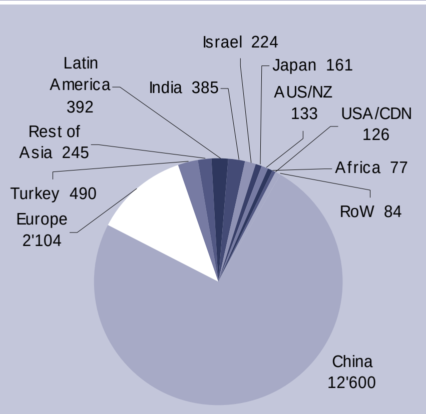
Fig. 5 shows the projected cumulative electrical or thermal capacity ($GW_{el/th}$) at y/e 2007 for wind, solar collectors, geothermal power, photovoltaics and CSP, as well as the energy generated from it in 2007 ($TWh_{el/th}$).[6]

Principal global markets

Global growth of 24% in 2006

There are still huge differences between national markets in terms of newly installed collector area. China, easily the biggest market, is roughly six times bigger than the European market. It is still booming (+20%). Newly installed capacity in 2006 came to 17,000 MW_{th} (24.3 million m^2), an increase of roughly 24% on 2005 (see Fig. 6). Around 74% of this capacity was installed in China. Apart from China, other important markets include Germany, Greece, Austria and also Turkey, Israel and Japan. The global solar thermal market in 2006 was worth EUR 4.4 billion[7].

Fig. 6: Global newly installed collector capacity in 2006 in MW_{th}: Total 17,000 MW_{th} (24.3 million m^2)



Source: Underlying data: W.B. Koldehoff, August 2007

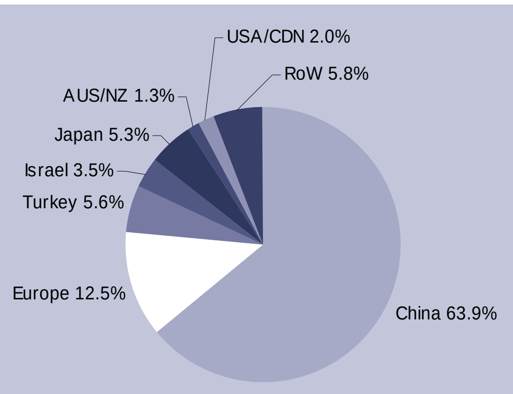
Global cumulative collector capacity up 20%

Fig. 7 illustrates the cumulative collector capacity currently in service in the individual countries and regions at the end of 2006. Compared with 2005 this capacity has increased by 20% worldwide to a total of 108 GW_{th} (154 million m^2). The geographical spread has stayed relatively stable. China is still easily the leader in terms of installed solar collector capacity, with a share of 64% or 69 GW_{th} (98 million m^2).

[6] In this study the installed solar collector capacity is not expressed in square metres, but rather in kilowatts of thermal energy using a conversion factor of 0.7 kW_{th}/m^2 . For a detailed description visit www.iea-shc.org

[7] This is based on an assumption for China, Turkey and Latin America of a price of EUR 112 (USD 150) per square metre of collector area and a price of 560 EUR/m^2 (800 USD/m^2) in Europe, based on 26.1 million m^2 of newly installed collector area

Fig. 7: Total global solar heating systems in service at y/e 2006. Total installed capacity is 108 GW_{th} (154 million m^2)



Source: Underlying data: W.B. Koldehoff, August 2007

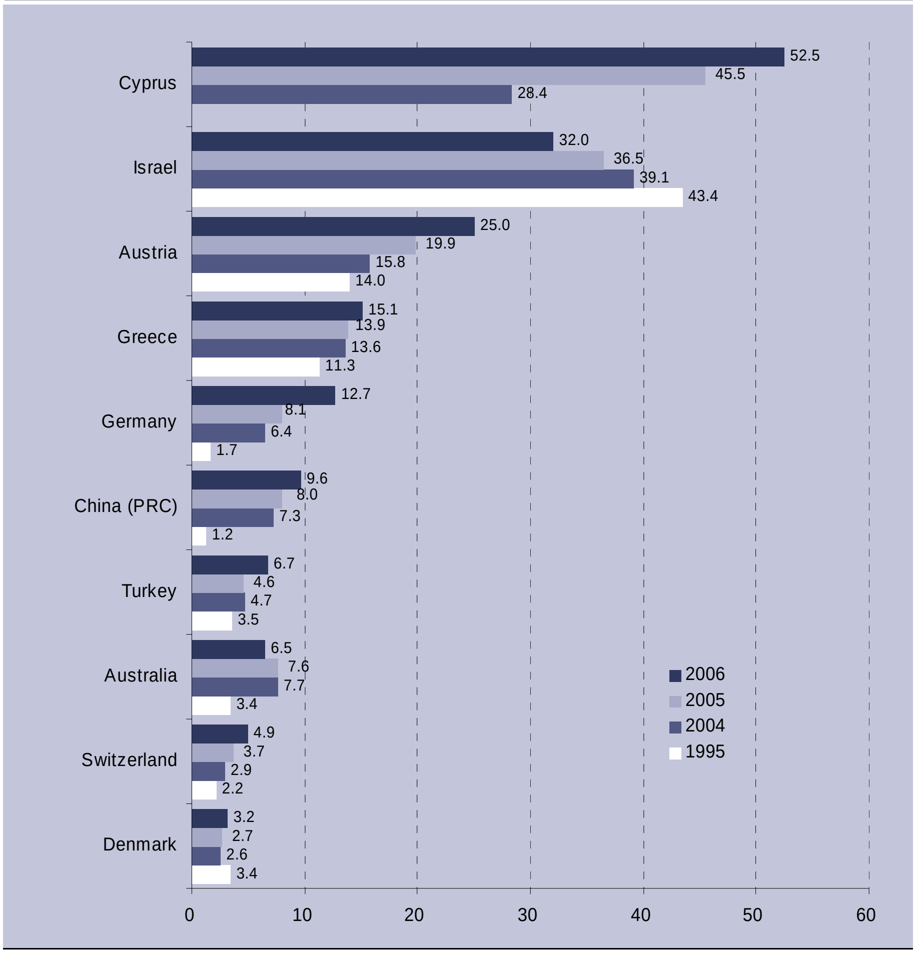
Top ten countries for solar collectors: Germany and Turkey experience highest per capita growth of +56% and +45% respectively

Measured in terms of “newly installed collector capacity per 1,000 inhabitants”, Cypress is clear leader. Its pace of capacity expansion has picked up significantly in recent years and has almost doubled (Fig. 8). Israel is in second place, although its pace of expansion has continuously fallen in recent years. A sharp increase in newly installed collector capacity per 1,000 inhabitants was also posted in Germany (+56%) and Turkey (+45%). But Greece (+8.6%), China (+24%), Austria (+25%) and Switzerland (+32%) have also experienced growth in “per capita" installations over the last three years. This figure is helpful in order to illustrate the performance of individual markets more effectively.

Enormous potential for solar heat, but heavily reliant on state subsidies

Australia is still suffering from a reduction in the level of state subsidies. This shows how sensitively a relatively young market responds to changes or uncertainties in subsidy programmes. In Israel a certain level of saturation now seems to have been reached. The level of installed collector area now lies at 540 m^2/1000 inhabitants. The figure for Austria is 160 m^2 and 145 m^2 inhabitants for Greece.

Fig. 8: Top ten countries – Market size per head of population: Annual newly installed collector capacity in kW_{th} per 1000 inhabitants



Source: Underlying data: W.B. Koldehoff, August 2007

China

China: world's biggest market still grew by 20% in 2006

With a 74% share of global installed collector capacity in 2006, China is the world's biggest solar thermal market – even without any state subsidy programmes. This is equivalent to newly installed capacity of 12.6 GW_{th}, a percentage increase of 20%. The cumulative capacity at y/e 2006 was around 68.7 GW_{th}.

90% of the systems are installed in private houses for heating water (a third in big cities and two thirds in suburbs and smaller towns), 10% in hospitals, schools, hotels, etc. Around 85% of the systems use thermosiphon technology, mainly with evacuated tube collectors. There is a trend towards higher quality flat-panel collectors with longer service life, especially for large showpiece projects. Future challenges lie mainly in improving the safey of systems and in integrating solar systems into the building façade in a more visually appealing way.

Solar collectors generate a market volume of EUR 2.08bn in 2006

To get a rough idea of the scale of China's market volume for solar thermal energy, we assume that each installed collector area costs 105 EUR/m^2 (150 USD/m^2). With the newly installed area of 19.8 million m^2 in 2006, the market volume comes to EUR 2.08bn. In 2010 an additional 25 million m^2 capacity is expected. That would correspond to a market volume of EUR 2.8bn.

Volume growth is expected to remain high for the coming years, because rural and suburban regions are likely to experience increasing energy shortages, with booming industry taking up more and more of the limited energy supply. The government's target is for a cumulative collector capacity of 100 GW_{th} in 2010, and 190 GW_{th} in 2020. The 2010 target should be achievable with a moderate growth rate of 15%. Growth would then only need to run at 7% up to 2020. According to solar industry calculations, a quarter of Chinese households would thus be fitted with a solar-powered water heating system.

Japan

Japanese market pauses for breath

Last year around 160 MW_{th} of new collector capacity was installed in Japan. This is a fall of 20% on 2005 (203 MWth). At year-end 2006 a total of around 5700 MW_{th} of collector capacity was in service. Up to the end of 2005 the government provided a subsidy of around EUR 100-140 EUR/m^2 for a collector with a closed-loop system (no thermosiphon). This represented about 10% of the investment costs. Subsidies stopped in January 2006, because the government thinks that the collector market is big enough and stable enough to stand on its own feet. It is now clear that this is not yet the case, and expansion has fallen back sharply. Consumers also see solar collectors as being slightly outdated, compared with photovoltaics. The government target of 25 GW_{th} cumulative collector capacity in 2010 is unlikely to be reached without additional supportive measures. This would require annual growth of over 25% in the years to come.

Turkey

Closed Turkish market is opening up – but has export ambitions as well

Last year the Turkish solar market grew by 490 MW_{th} , a 46% increase on 2005. Per capita installation was 6.7 kW_{th} per 1,000 inhabitants in 2006, placing Turkey seventh in the world rankings. Ordinary Turkish citizens cannot affort solar collectors without state subsidies. It is the most cost-efficient way to provide hot water. Because domestic demand is so high, a strong Turkish solar industry has developed. Over the years the quality of the systems has improved significantly, in particular in a drive to increase exports to Western Europe. Like Israel, Turkey was a relatively closed market for a long time, with its own product standards. There are now joint ventures between EU companies and Turkish firms to boost sales of highly efficient solar collectors in the top price segment. These products are particular attractive to the Turkish tourist industry and its large hotel complexes.

USA

Rosy outlook for the US solar thermal market

In the USA, solar collectors (mainly unglazed black tube systems) have been used exclusively to heat swimming pools. This market has enjoyed average annual growth of 15% since 1997 – albeit from a comparatively low starting point. Three quarters of the systems are being installed in California and Florida. As oil and gas prices continue to rise, more interest is now being paid to combined solar hot water and heating systems, especially in states located in the sun belt. This considerably shortens the payback period. In addition many federal states have set up incentive programmes for both thermal and PV solar systems. The recently passed national Energy Bill proposes tax credits for the installation of solar systems and explicitly includes solar heating systems as well. The new tax incentives at US federal level and the Californian solar initiative which provides

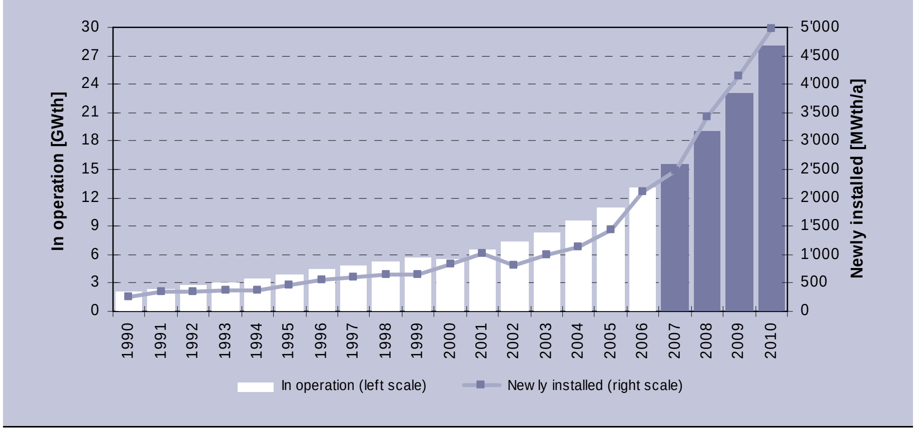
USD 100m of subsidies for solar thermal R&D should boost the rate of market growth. The US market for glazed collectors grew 50% to 126 MW_{th} in 2006, and our forecast for 2007 and 2008 is 180 and 250 MW_{th} of newly installed capacity respectively.

Market trends in Europe

Dynamic growth of 45% in 2006

After dynamic growth of 26% in 2005, the European solar thermal market[8] advanced another 45% in terms of newly installed solar collector capacity. This is equivalent to a capacity of 2100 MW_{th} or 3 million m^2 of collector area. This strong uptrend clearly shows that solar thermal energy is attracting more and more attention both from EU and national politicians.

Fig. 9: Development of solar collectors in Europe (EU 27 + CH). Forecast for 2007 to 2010: 2500, 3400, 4100 and 5000 MW_{th}



Source: ESTIF, June 2007; W.B. Koldehoff, August 2007 and own estimates

For this year we anticipate another moderate growth rate of 18% to 2500 MW_{th}. For the next two years (2008 and 2009) we predict growth will reach 38% and 21% respectively (Fig. 9). This growth should be supported above all by the subsidy programmes introduced for solar thermal energy in various countries. Spain even went one step further and following regional and municipal initiatives is now requiring the use of solar hot water systems in its national building regulations for newbuild and renovation projects.

87% of collectors installed in Germany, Austria, Greece, Spain, Italy and France

Sales of solar collectors in Europe are now concentrated in six key markets: Germany, Greece, Austria, Italy, Spain and France (Fig. 10). 87% of new capacity is installed in these nations. Of the other countries, above-average growth rates were posted in the UK, Belgium and Poland, although starting from a relatively low level. All 12 new EU member states had a higher than average growth rate of 30% and collectively command a market share of around 6% of solar collectors currently in service.

[8] ESTIF: European Solar Thermal Industry Federation, www.estif.org; Trends and Market Statistics 2006, June 2007; EU 27 + CH

Fig. 10: Solar heating market in Europe 2006: Overview listed by market share in MW_{th}

Country	2006 in operation (MWth)	EU-market (%)	Installed 2005	Installed 2006	Market growth	2007 Market prognosis	2008 Market prognosis
Germany	5'652	42%	679	1'050	55%	1'050	1'361
Greece	2'301	17%	154	168	9%	189	206
Austria	1'828	14%	163	205	25%	245	307
Italy	530	4.0%	89	130	46%	200	292
Spain	492	3.7%	75	123	64%	228	373
Switzerland	311	2.3%	27	36	33%	46	60
Denmark	254	1.9%	15	18	14%	22	25
The Netherlands	223	1.7%	14	11	-26%	13	13
France (EU)	431	3.2%	85	154	81%	217	393
Sweden	165	1.2%	16	20	24%	24	29
Great Britain	176	1.3%	20	38	93%	49	95
Portugal	127	0.9%	11	14	25%	17	21
Belgium	73	0.5%	14	25	78%	32	56
Norway	18.6	0.1%	2.8	2.8	0%	3.5	3.5
Finland	11.9	0.1%	1.4	2.1	50%	3.2	4.7
Ireland	11.1	0.1%	2.5	3.5	43%	7.0	10.0
New EU-12	800	6.0%	80	104	30%	132	172
Total	**13'403**	**100%**	**1'450**	**2'104**	**45%**	**2'475**	**3'421**

Underlying data: ESTIF, June 2007; W.B. Koldehoff, August 2007 and own estimates

Germany

German market jumped by 55%

Compared with 2005 the sales of solar collectors in 2006 rose by a very impressive 55% to 1050 MW_{th} of newly installed capacity. Germany is Europe's biggest market (42%), with approximately 5,600 MW_{th} cumulative solar collector capacity currently in service. The government target of 7 GW_{th} cumulative solar collector capacity by 2006 was not achieved, however. Despite two reductions in the German market incentive programmes, this market has comfortably outperformed the average European growth rate. According to a representative survey of the Soko Institute based in Bielefeld, over one million households in Germany are now using solar thermal power.[9] In addition, around 800,000 additional German homeowners are planning to purchase solar heating system over the next 24 months.

2007 is a year of uncertainty, and the market is stagnating

Despite the surveys, things have not been going so smoothly this year in the German solar thermal power industry. Despite the climate debate, the German market's performance in the first six months has been the worst ever. Investments in the area of energy-saving heating systems have fallen by almost 25%, especially in the area of modernisation. This was in response to uncertainties in the market and poor communication between politics, industry and end consumers. In view of the tentative situation we expect the German market to stagnate in 2007, with newly installed capacity stuck at roughly 1000 MW_{th}.

Regenerative heat has been underestimated and could already be profitable

According to the Federal Industrial Federation of Home Energy and Environmental Technology (BDH)[10], renewable heat is already profitable. The solar thermal segment can play a bigger role in relation to climate protection, as in-

9 www.soko-institut.de

10 www.bdh-koeln.de

vestments in this area are already profitable. While renewable energies in the field of power generation have been steadily gaining market share for years now and at the end of this year will cover 15% of demand, regenerative heating sources have so far only contributed six percent of the energy mix. By 2020 this share is set to rise to around 12%. In the opinion of energy experts, this target can only be met if the bulk of the approximately 600,000 overhauled or newly installed boilers every year convert to renewable energy.

Regenerative Heat Act is desperately needed as a future driver

According to comments from the Federal Minister of the Environment, Sigmar Gabriel, a dynamic expansion of renewables in the solar heating segment is only possible if stable overall conditions and investment security can be provided for equipment manufacturers. The minister wants to pass a Regenerative Heat Act (EEWärmeGesetz) before the end of the year. The details are still being finalised, but the act is intended to bolster the faltering funding initiatives for renewables and to prescribe a minimum quota of renewables for the installation of new heating systems. The proposed legislation has been warmly received by the renewable energies sector, environmental associations and the German Tenants' Association. If a regenerative heat act does come into force this year, it would certainly help to boost investment and growth. In addition, new incentive guidelines came into effect on 2 August 2007 as part of the market subsidy programme. The subsidy rates have been increased by 50% and apply to all applications submitted to the Federal Office of Economics (BAFA) as of that date.[11]

Two pillar principle: energy efficiency and renewable energies

Saving energy is important, but not in itself sufficient for the effective protection of consumers from rising oil and gas prices, as well as climate change. Efficiency and renewable energies are two pillars of climate and consumer protection and must be pursued in tandem.

German manufacturers dominate the domestic market with a market share of around 62%

Germany experienced incredibly dynamic growth last year and is still by far the biggest market. In the case of flat-panel collectors, the percentage of the market accounted for by "made in Germany" (62%) and "imported" (38%) goods has swung in favour of German manufacturers, with a total of around 1350 Tm² collector area. With evacuated tube collectors, nearly 60% or around 150 Tm² were made in Germany. With a total volume of approximately 1.4 million m^2, Germany became Europe's biggest producer in 2006. Export volumes rose sharply to around 450 Tm², or around a third of production output. This is particularly down to the performance of big players whose exports also make them market leaders in other countries in some cases (France, Spain).

Cost savings have also been achieved in recent years following more industrialised manufacturing and economies of scale in marketing and distribution. Increasing concentration is also apparent on the production side, while at the same time distribution is now spreading more to providers of traditional boiler systems.

Situation steadily improving for solar thermal power

In Germany the attractive payments for solar energy fed into the mains grid seem to have made solar heating slightly less popular with owner occupiers. By

[11] www.bafa.de/bafa/de/energie/erneuerbare_energien/

way of comparison, the German PV industry generated sales of EUR 3.7bn in 2006, while the solar heating sector “only” earned EUR 1.2bn. The high oil and gas prices, coupled with the growing awareness of end consumers, has ensured that solar thermal power has become more attractive again as an alternative to photovoltaics. As far as climate protection is concerned, solar heating definitely deserves more support, since specialist publications show that when in service a solar collector saves well over twice as much CO_2 (relative to area) than a comparable PV system.

Austria

Collector production up 60% in 2006...

In 2006 Austria’s collector production was roughly 1.13 million m² (790 MW_{th}), compared with 0.7 million m² or 490 MW_{th} in 2005. Collector production was therefore up by more than 60% on the previous year, compared with a growth rate of 36% in 2005. Roughly 75% (0.85 million m²) of the total production volume was exported to more than 20 countries. Germany leads the way with 68.3%, followed by Italy with 9.6%, France with 6.2% and Spain with 5.6%. Other export countries include China, the US and Romania.

...and newly installed collector area increased 25%

The glazed collector surface area installed in Austria in 2006 came to 292,000 m² (233,000 m² in 2005, or +25%). This corresponds to a thermal capacity of 205 MW_{th}. At the end of 2006 the cumulative capacity in service therefore came to 1828 MW_{th} (y/e 2005: 1623 MW_{th}).

Combi systems have a market share of 35%

According to company information, the areas of application for the solar thermal systems installed in Austria in 2006 were as follows: 65% for solar-powered hot water systems and 35% for solar-powered systems with integrated heating – the same constellation as in 2005. The latter application therefore seems to be gaining in popularity, especially in buildings designed for low-energy consumption. The percentage of solar thermal systems fitted as part of building renovation was 35% in 2006.

In 2006 solar thermal power generated estimated sales of EUR 402m in Austria. This compares with EUR 270m in 2005 (+ 49%).

Market prognosis for Austria up to 2010

Austria’s solar thermal market posted average annual growth of 15% during the period 1990-2000. If additional market impulses manage to fuel this growth up to 2010, Austria would have almost 3000 MW_{th} collector capacity installed in this Kyoto target year. Our forecasts of newly installed capacity for the Austrian market are 245 MW_{th} for 2007 and 307 MW_{th} for 2008.

At the moment barely 2% of the total demand for low-temperature applications up to 100°C is covered by solar energy in Austria. This percentage is set to increase to 15% by 2020, and in the long run solar energy will play a key support role in securing a climate-friendly and price-stable energy supply.

Greece

Greece needs new solar applications for cooling or preparing drinking water

In 2005 Greece only experienced a growth rate of 3% to 154 MW_{th}. In 2006, however, growth bounced back to +9% or 168 MW_{th} newly installed capacity. This is well below the European growth rate of 45%. The cumulative installed capacity per 1000 inhabitants is 208 kW_{th}, the third highest figure after Israel and Austria, and the market has experienced a certain degree of stagnation. Additional stimulus could come from the wider promotion of systems for solar-assisted cooling or desalination. The industrial and commercial segment also presents substantial potential for solar thermal systems. Our forecasts of newly installed capacity for the Greek market are 189 MW_{th} for 2006 and 206 MW_{th} for 2007.

Switzerland

Swiss market: solar heating continues to flourish

Last year a total of 36.3 MW_{th} new capacity was installed in Switzerland.[12] This is equivalent to 32.4% growth on last year. The installation rate has therefore increased significantly for the fourth consecutive year. The lion's share (97%) was flat-plate collectors. Total installed solar thermal capacity therefore comes to over 285 MW_{th}. High oil and gas prices and the "solarbegestert" incentive programme launched four years ago are having a clear impact and have triggered a sharp trend reversal. Our forecasts of newly installed capacity for the Swiss market are 46 MW_{th} for 2007 and 60 MW_{th} for 2008.

The introduction of a CO_2 tax on heating oil and gas as of 2008 provides property owners with an additional incentive to reduce their consumption of fossil fuels. The imposition of tougher energy consumption regulations for buildings agreed by the directors of the cantonal energy authorities are pointing in the same direction. In the longer run, solar thermal technology could account for 35% of Switzerland's heating requirement for residential properties.

Other markets

Growth rates still high in France

France's collector market has continued to enjoy dynamic growth. After growing more than 120% in 2005, the market advanced another 81% in 2006. The state subsidisation programme "Plan Soleil" has provided an important stimulus and ensured that around 154 MW_{th} new capacity was installed in 2006. Since January 2006 up to 50% of the purchase cost of solar heating systems can be offset against income tax. The potential is still massive, because the per capita collector area in France is still very low. Our forecasts of newly installed capacity for the French market are 217 MW_{th} for 2007 and 393 MW_{th} for 2008.

"Solar-friendly" building regulations in Spain

Another traditionally promising candidate – the Spanish solar market – posted disappointing growth of just 19% in 2005. In 2006 the growth rate rebounded to 64%, corresponding to a newly installed capacity of 123 MW_{th}. This is definitely the result of new building regulations which have since been passed by almost 40 municipal and local authorities. They prescribe a "Barcelona model": all new-builds or renovated properties must install solar-powered hot water systems. This legislation has been extended to cover the entire country as of September 2006. This law requires 30 -70% of household hot water consumption to be covered by solar thermal power. Our forecasts of newly installed capacity for the Spanish market are 228 MW_{th} for 2007 and 373 MW_{th} for 2008.

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[12] Solar - Schweiz. Fachverband für Sonnenenergie, market survey 2005; www.swissolar.ch

Global market trends up to 2020

China constantly growing and will meet its targets

In 2006 the world's newly installed collector capacity was 18.3 GW_{th}, roughly 33% higher than in 2005. For the year 2007 we predict that newly installed collector capacity worldwide will reach around 23 GW_{th} (32.9 million m^2), which is 25% more than last year. This growth will come mainly from China and Europe, but also from other non-European countries. For several years now China has shown itself to be a dynamic and self-sufficient market with annual growth rates of over 20%. Demand for solar collectors will continue to rise in future because the Chinese economy is booming. Taking into consideration the government's renewable energy projects mentioned earlier and soaring fossil fuel prices, we think this current trend is set to continue. The Chinese government looks as though it will manage to achieve its ambitious targets for 2010 and 2020.

New markets developing

In future we can expect to see other markets developing in sunbelt regions, such as Southern Europe, the US and Australia and other emerging markets such as India, Indonesia, Mexico and Brazil.

Growth in Europe at least 20% up to 2010

After collapsing in 2002 (-22%), the European market has quickly recovered and stabilised, and reverted to 45% growth in 2005/06. By 2010 we expect average annual growth of over 20%. If, however, new legislative or political measures provide additional support in different countries and at EU level, and gas & oil continue to rise, growth rates could well be much higher. Solar cooling and air conditioning offer significant growth potential as well.

New EU directive on solar thermal heating would provide the necessary boost

In its recent White Book, the European Commisison has set a 2010 target of 70 GW_{th} for installed solar collectors. At y/e 2006 the total installed capacity was 13.4 GW_{th}. Given the current growth rates, we estimate that the EU target will not be reached until 2013 at the earliest.

Heating and cooling with renewable energies

Of the total primary energy consumption in the EU, 40% occurs in buildings, 32% in transport and 28% in industry. Room heating and heating up water account for 85% of energy consumption in buildings. This magnitude is unfortunately totally out of proportion to the public and political attention devoted to heating energy. To provide stronger support to solar heating in the important energy segment of "heating and cooling", there need to be more effective public subsidisation programmes or legal measures, such as the previously mentioned "Barcelona model" in Spain or the planned "Regenerative Heat Act" in Germany. The European industry association ESTIF, together with the European Renewable Energy Council (EREC)[13] and other organisations, has published a declaration calling for an EU directive to ensure that renewable energies (solar thermal power, biomass and geothermal energy) will cover roughly 25% of heating and cooling energy by 2020.

Global growth of 25% up to 2010

The annual global growth rate of the solar collector market should average roughly 25% up to 2010 (in terms of newly installed capacity). In 2010 we there-

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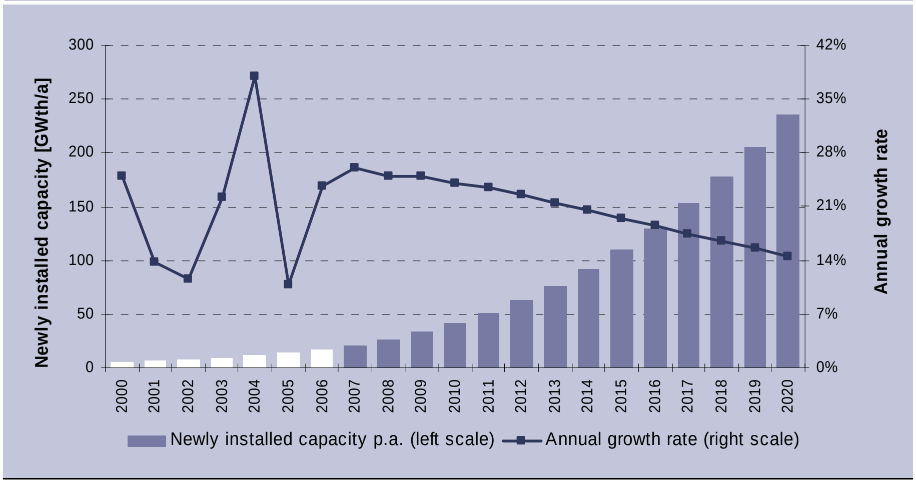
13 Joint Declaration for a European Directive to promote renewable heating and cooling; European Renewable Energy Council (EREC), Brussels, April 2005; www.erec-renewables.org

fore expect a market volume of 45 GW_{th}. This is equivalent to a monetary value of around EUR 25 billion. This would ultimately result in total installed collector capacity of 225 GW_{th} worldwide by the end of this decade. With the increasing absolute size of the market, we expect average growth will then ease back in the following decade (2011- 2020) to around 18% p.a. The global market for newly installed solar collectors would therefore reach a volume of approximately 253 GW_{th} in 2020 (see Fig. 11). For the future we are confident that the global trend towards solar thermal power will remain intact in the coming decades.

Fig. 11: Sarasin forecast for global solar collector market. Newly installed collector capacity in GW_{th} per year



Source: Sarasin, 2007

Solar thermal power stations

Fields of application

Concentrating Solar Power (CSP)

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

World's appetite for energy continues to grow

The International Energy Agency (IEA) predicts that world energy demand is set to grow by more than 50% up to the year 2030. This represents an additional threat to the security of energy supply and the environment, as well as escalating energy prices. Many countries are therefore showing a lot of interest in renewables. Solar thermal power stations are usually designed to generate grid electricity and are therefore mostly large installations with an output of 30-200 MW_{el} , working at high temperatures (400-800°C). To meet the high demand for energy worldwide, these systems are currently the only solar technology capable of replacing comparably sized traditional power stations powered by fossil or nuclear fuels.

Positive market outlook for CSP

Political incentives in Spain are now enabling new CSP power station projects to be realised. In Spain, electricity generated from solar thermal power is entitled to a legally guaranteed feed-in tariff of roughly EUR 0.21/ kilowatt hour over a period of 25 years. Since the technology used for solar thermal power generation has significant cost-saving potential, it will, with the help of the global market incentives for solar thermal power, be able to compete with peakload and medium-load power generated by fossil fuels in as little as 15 years' time.

CSP systems have a good LCA profile, with low materials and space requirements

Solarthermal power stations score very well in an environmental life cycle analysis (LCA). The energy recovery time of five months is very low, even when compared to other forms of renewables. Of all the CSP technologies, the parabolic trough uses the least materials, and also takes up far less space than biomass, wind energy and hydroelectric power (with the exception of dams in mountainous areas). As they can only be constructed in the arid zones of this planet, there is very little competition for land usage. Solar thermal power stations can be installed in the Earth's sunbelt, in a latitude of up to 35 degrees north or south of the equator. Thanks to their high level of efficiency, and very low power generation costs, installations using parabolic trough technology have the potential to produce electricity at competitive prices in these sundrenched regions.

Solar power stations combined with gas & steam power stations or a storage system

Apart from 'pure' solar systems, hybrid systems are also planned that are integrated in conventional power stations (e.g. gas and steam) and are responsible for generating some of the steam during daylight hours, thereby saving on fossil fuels. Besides this, more and more systems are being fitted with a heat storage system (e.g. phase-changing media such as molten salts), in order to tailor electricity production more effectively to demand. This allows expensive peakload power to be generated as well.

Off-grid electricity and heat generation

Apart from centralised generation of electricity, smaller off-grid power plants based on parabolic trough technology can be used to generate electricity or industrial process heat (for example, to replace diesel generators).

Existing plants and planned projects

First commercial CSP systems built in the eighties in California and Spain

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

Some new power station projects now in the planning phase

In the last four to five years plans have multiplied for new power generation projects in response to technological advances and also more attractive political and economic conditions, including climate protection agreements, soaring oil prices, subsidy programmes for renewable energies and generous fixed-rate payments for solar energy supplied to the mains grid. However, such large-scale projects involve protracted procedures to obtain planning permission and secure the necessary funding. But things are now moving along, especially in Spain and the US.

German solar tower as a pilot scheme

Work started in October 2007 on the construction of a single solar tower power station in Jülich, Germany. With a capacity of 1.5 MW, it is intended as a pilot scheme for researchers, engineers and system designers. As of November 2008 it should generate 1000 MWh of electricity p.a. This corresponds to an energy yield of 666 kWh/kW.

Spain's PS10 solar tower conneted to the grid since March with an output of 11 MW

For comparison purposes: the PS 10 solar tower that has just come on stream in Seville has a capacity of 11 MW and is capable of supplying 23,000 MWh of electricity p.a. This corresponds to approximately 2100 kWh/kW. The 624 mirrors (heliostats) each have a surface area of 120 m^2 and concentrate the sunlight onto a receiver at the top of the 115 m high tower. The project took 54 months to implement and cost EUR 35m (approx. 3200 EUR/kW). The power station is operated by a Spanish company. Additional solar power stations with a total capacity of 300 MW_{el} are are due to be built up to 2013 at the same location, including Dish-Stirling systems, parabolic trough collectors and PV generators with concentrator systems.

Schott Solar has most know-how in several solart technologies

The German technology company *Schott* plans to build a second production facility of solar receivers in Spain. Only last August, *Schott* opened a new production line at its Bavarian location. When the second receiver factory comes on line in the Seville region, *Schott* will be able to double its production capacity from the start of 2008.

Market outlook

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 US, Mexico, southern Europe, Africa, Middle & Far East, India and Australia. The following conclusions can be drawn from the technical progress achieved and the improved overall conditions:

- The cost efficiency of these technologies, i.e. comparable costs to conventional power station technology, looks as if it will become more acceptable in the near future. Electricity generation costs of around 15 Cent/kWh are already realistic for the power stations currently under construction.
- Unlike photovoltaics, this technology is suitable for large power stations that can be extensively used for central power supply and in the long term could even be a substitute for power stations using nuclear and fossil fuels.
- The subsidy programmes and incentives in Spain, China and the US 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 relies – 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.

Significant investments needed for the breakthrough

One of the biggest obstacles preventing solar thermal power stations from making a breakthrough is the high level of investments required. This is currently around 3300 - 2500 EUR/kW, compared with around 500 EUR/kW for a modern gas-fired power station. In the mid-term (approx. five years), however, capital costs could be cut to around 1500 - 2000 EUR/kW, or roughly the same amount that would be required to construct a new nuclear power station. The technology’s cost-efficiency therefore depends heavily on the financing opportunities and conditions, and on general interest rate trends, among others. Solar Millennium, for example, had to spend EUR 20m on bringing the technology for the two Spanish power plants to market and developing the projects. The entire investment cost for realising the three solar thermal powers stations each with a capacity of 50 MW in Andalucia is in the region of EUR 500 m.

The technology is ready, according to the industry association

According to a study by Greenpeace[14] and the European Association of the Solar Thermal Power Industry ESTIA, more electricity could be generated worldwide by solar thermal power stations in 2040 than is currently generated by nuclear and hydroelectric power stations. By 2040 five percent or 600 GW_{el} of electricity consumed worldwide could come from solar thermal power stations – despite the fact that electricity consumption is expected to double by then. The

14 Concentrated Solar Thermal Power – Now! Greenpeace, ESTIA, Solarpaces, Brussels, September 2005

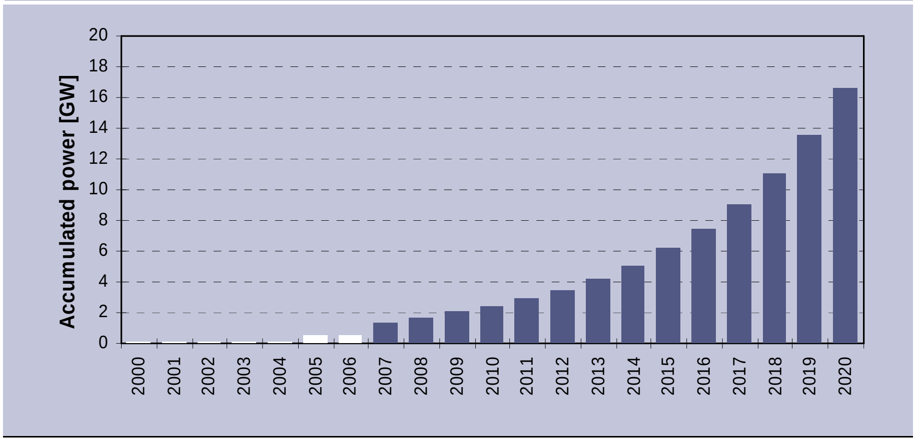
study gives practical advice on what needs to be done to ensure the technology becomes established. The Middle East and North Africa could assume a pioneering role. Up to 100 million people living in the sunniest areas on earth could make use of this clean energy source.

Conclusion: the outlook is brighter than ever

The future development of solar thermal power plant technologies is heavily dependent on the experiences operating the first power stations connected to the grid at the end of 2007 and beginning of 2008. This will be the first opportunity to really test the reliability of the latest solar thermal power stations.

In 2007 worldwide the newly installed capacity could already surpass 800 MW_{el}. If these installations fulfil expectations regarding reliability and cost efficiency, it could lead to further exploitation of the enormous market potential and a surge in growth. The global market initiative for solar thermal power stations (CSP GMI)[15] wants to create new solar thermal capacities of around 5.0 GW_{el} by 2015. Given the current project status, this goal seems ambitious, but not impossible. According to Fig. 12, cumulative capacity of approx. 2500 MW_{el} (2.5 GW_{el}) should be achievable if the concrete projects are realised by 2010. Additional projects are still undergoing a feasibility study, i.e. the drop-out rate before actual realisation is likely to be relatively high. Until 2020 we forecast a total installed capacitiy of 16 GW_{el}.

Fig. 12: Predicted expansion of solar thermal power stations up to 2020



Source: Sarasin, 2007

15 GMI brochure, www.solarpaces.org

CO_2 abatement through solar energy

Climate change and its consequences

Man-made greenhouse gases are responsible for climate change

The rise in atmospheric temperature as a result of soaring greenhouse gas emissions is becoming increasingly obvious. If the current trend continues, a CO_2 equivalent concentration (CO_2e) of 550 ppm will be reached in 2035, resulting in a temperature increase of almost 3°C.[16]

According to the Stern Report commissioned by the British government and published in October 2006, the economic costs of climate change over the next two centuries are estimated to come to at least 5% of global per capita income. If the consequences for the environment and human health are taken into consideration as well, the costs climb to around 11% of global GDP. If one also takes into account the latest scientific findings on feedback mechanisms and the fact that the world's regions are affected differently, the costs increase to around 20% of global GDP.

Preventing climate change and subsequently reducing these enormous costs requires measures capable of reducing greenhouse gas emissions as quickly as possible. To stabilise greenhouse gases released into the atmosphere in the long run, global emissions worldwide must be reduced to 7 billion tons of carbon (7 Gt C), which is as much as our natural ecosystems can absorb. Four different types of measure are available for this:

- Reducing demand for energy-intensive goods and services;
- Improving energy efficiency;
- Reducing greenhouse gases not originating from transportation (e.g. preventing the destruction of rainforests);
- Switching to energy sources that are not based on fossil fuels.

The last point in particular frequently triggers a heated discussion about the effective reduction potential and the costs of using more renewable energies. A large-scale project initiated by the city of London[17] examined the CO_2 prevention costs of different technologies and measures, and their potential to reduce greenhouse gases. Based on the two energy scenarios of the IEA – "reference scenario" (also known as "business as usual", BAU) and "alternative scenario"[18] – the individual CO_2 stabilisation wedges for each reduction option were worked out. The fact is that approximately 7 Gt C were emitted in 2004 in the form of carbon dioxide (25.6 Gt CO_2). The projections for the BAU scenario expect approximately 14 GtC/a for 2054. The CO_2 reductions anticipated by 2054 for the

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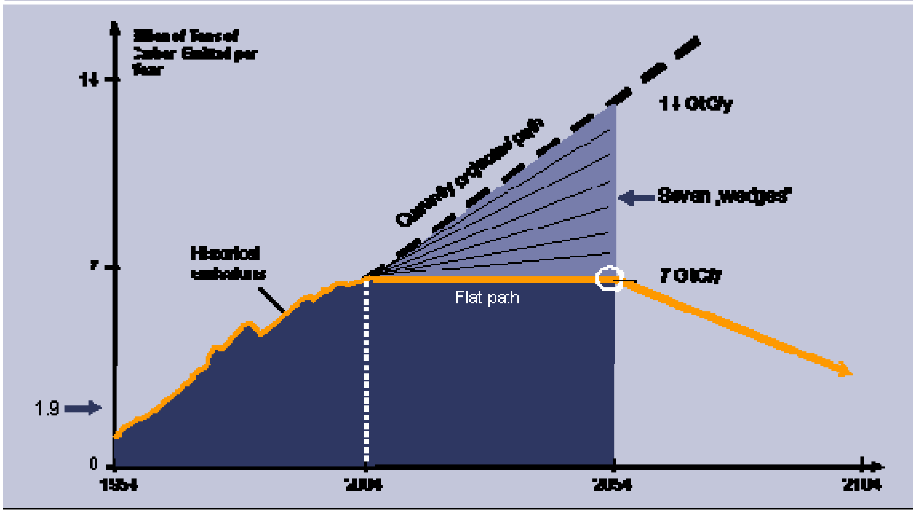
16 Sir Nicolas Stern: The Economics of Climate Change, report commissioned by the UK Treasury, published on 30 October 2006

17 www.london-accord.co.uk

18 IEA World Energy Outlook www.worldenergyoutlook.org

individual reduction options can be represented as a “stabilisation wedge”, a model developed by the two scientists Pacala and Socolow.[19]

Fig. 13: The seven wedges strategy (Pacala & Socolow)



Source: Pacala und Socolow, 2004

According to the IEA reference scenario, global primary energy consumption is set to rise from 130,000 TWh in 2004 to around 200,000 TWh in 2030. This is equivalent to an annual average growth rate of 1.6%.

Here the different CO_2 abatement strategies are divided into subsegments or so-called "wedges" (see Fig. 13). A single wedge corresponds to a strategy that prevents 1.0 GtC/a by 2054. Seven such wedges, or abatement options of 1 GtC/a each, are required to stabilise CO_2 emissions. The next section identifies the contribution made by the solar industry (abatement costs and potential).

CO_2 abatement potential of solar energy

When determining the global CO_2 emissions that could be prevented through the use of solar energy, we first need to calculate how much CO_2 can be saved through solar energy per kWh of electricity or heat generated. Here the main criterion is the “net CO_2 balance” of solar energy, i.e. the CO_2 reductions achieved in comparing the electricity generated from the future technology mix (coal, nuclear, gas, etc.) less the CO_2 emissions generated in the production phase of the solar energy system itself.

Life cycle analysis considerations (CO_2 emissions from production phase)

Photovoltaics:

Two-thirds reduction in production-related CO_2 emissions by 2015

Current results of life cycle analyses (LCAs) for photovoltaics systems show (see Fig. 14) that the bulk of resource consumption and many emissions originate from the energy used to manufacture the solar-grade silicon, wafers, cells and modules. The electricity mix at the location of the production sites therefore plays

[19] "Stabilization Wedges: Solving the Climate Problem for the next 50 Years with Current Technologies" S. Pacala and R. Socolow, Science, August 13, 2004

a particularly important role.[20] Due to rapid advances in production technologies, the LCA and CO_2 emissions will definitely diminish over the course of time.

Abb. 14: Greenhouse gases emitted during the production of PV systems

	String-ribbon silicon (ribbon-Si)	**Multi-cristalline silicon**	**Mono-cristalline silicon**	**Cadmium-telluride (CdTe) thin-film**
Today	Standard technology 2004	Best available technology 2004	Best available technology 2004	1 company *(First Solar)*
Efficiency	11.5%	13.2%	14.0%	9.0%
Greenhouse gas emissions (GHG) (g CO_2/kWh)	29	32	35	25
Mid-term (2010)				
Efficiency	15%	17%	19%	15%
GHG-Emissionen (g CO_2/kWh)	16	15	15.5	15
In future (2015)				
GHG-emissions (g CO_2/kWh)	10	10	10	10

Source: Alsema et al., Sept. 2006 (Mediterranean location), own estimates

Projections for future developments show that greenhouse gases emitted during the production of the individual PV technologies will be approaching roughly 15 g CO_2/kWh.[21] In the long term (from 2015 onwards) we expect a figure of 10 g CO_2/kWh for all PV technologies due to further optimisation and scale-up.

Solar collectors:

Proportion of CO_2 emissions originating from production is <5%

The main determinants for the production-related CO_2 emissions of solar collectors are not just the collector itself, but above all the various additional components of the system (i.e. the installation as a whole). These include the steel used for the hot water storage tank and the copper and plastic used for the pipework. Most of this is also required for a conventional hot water and heating system, so does not need to be installed in addition. Running the collector consumes a certain amount of electricity for the pumps. The manufacture of the collector's coating does not cause any significant CO_2 emissions.[22] The amount of CO_2 emissions caused by the production of the additional system components is currently around 0.02 kg CO_2/kWh. Certain technological advances will lead to this level being halved from 2015 onwards.

Concentrating solar power (CSP) plants:

Production responsible for less than 5% of CO_2 emissions

Energy-intensive components of a CSP power plant include the actual mirror and tube systems made of glass, the entire assembly and support systems made of steel and concrete, as well as the conventional steam turbine and generator. Because of the comparatively large quantities of heat and electricity produced, the production-related CO_2 emissions should not be significantly higher than for a

[20] ecoinvent 2000 – Review and update of life cycle analyses for energy systems, Roberto Dones, Paul Scherrer Institut (PSI) commissioned by Switzerland's Federal Department of Energy (BFE), December 2003. www.admin.ch/bfe
[21] Alsema, de Wild-Scholten & Fthenakis: environmental impacts of PV electricity generation – a critical comparison of energy supply options. Presented at the PVPS Conference in Dresden, Sept 2006
[22] ditto, see 8

conventional fossil-fuel power station. These are currently 0.025 kg CO_2/kWh and will reach around 0.01 kg CO_2/kWh from 2015 onwards.

Forecast for CO_2 reduction up to 2030

The reduction in CO_2 emissions up to 2030 through using solar energy is the product of two factors:

- A "net" CO_2 saving per kWh of electricity or heat generated by the solar energy system, i.e. less the CO_2 emissions during production, as mentioned previously. This depends on the power efficiency of the solar energy system at the relevant location and the mix of primary energy sources that is replaced by solar energy. This varies enormously from one region to another and will also be subject to change in the future.
- Market penetration by solar energy (or the amount of electricity and heat generated by solar energy in future): these quantities are based on our respective market forecasts.

Photovoltaics:

Assumptions for CO_2 abatement through PV systems

The power efficiency of a PV system depends on its location, as it is directly linked to the amount of sunshine. Depending on the location, annual yields can vary from 900 to 1600 kWh/kWp*a. For our calculation we use a weighted average of 1200 kWh/kWp*a. The exact CO_2 saving per kWh of PV electricity generated varies depending on the field of application. It can range from the replacement of an inefficient kerosene lamp with CO_2 emissions of up to 25 kg CO_2/kWh in Africa to the replacement of peakload electricity from power stations fuelled by natural gas with an emission factor of 0.47 kg/kWh. Viewed on a global basis and across the entire forecasting period, a reduction factor of 0.6 kg CO_2 per kWh of PV electricity is assumed. This is a relatively conservative assumption (compare the forecasts in the EPIA/Greenpeace publication Solar Generation IV – 2007).[23]

Fig. 15: Estimated CO_2 abatement through the use of solar energy

	Photovoltaics	Solar collectors	Solar thermal power stations
Service life (years)	25	20	25
Spectrum of energy output (kWh/kWp*a)	900 - 1'600	300 - 1'000	2'300 - 2'800
Average (kWh/kwp*a)	1'200	700	2'500
CO_2 reduction (kg CO_2/kWh)	0.5 - 25	0.25 - 0.65	0.47 - 1.2
Average (kg CO_2/kWh)	0.6	0.4	0.6
Production-related CO_2 emissions (kg CO_2/kWh)	0.03 (2006); 0.01 ab 2015	0.02 (2006); 0.01 ab 2015	0.025 (2006); 0.01 ab 2015
Net CO_2-reduction (kg CO_2/kWh)	0.57 - 0.59	0.38 - 0.39	0.575 -0.59

Source: Bank Sarasin 2007

CO_2 abatement through PV of 1.2 Gt CO_2 by 2030

Over the entire period 2006 – 2030 we expect the average annual growth rate of newly installed global capacity of PV systems to reach 22%. Based on these assumptions, the global reduction in CO_2 emissions should climb to around 1.2 Gt CO_2 in 2030, taking our forecast of 2000 TWh PV electricity.

[23] Solar Generation IV – 2007, Greenpeace and EPIA, Sept. 2007, www.epia.org

Solar collectors:

Depending on the field of application (grey water, combined system with heating booster, etc.), the local climate conditions and the size of the systems, the annual energy yields per square metre of collector surface area range between 300 kWh/kW_{th} for solar combined systems (hot water and heating) in northern zones and 1000 kWh/kW_{th} for hot water systems in southern regions. For our calculations we use the average value taken from the IEA-SHC report, 700 kWh/kWth*a. [24] As a global average CO_2 reduction factor we also use the value 0.4 kg CO_2/kWh_{th}. Here too the spectrum of CO_2 reduction is very broad. It ranges from the replacement of older oil-fired systems with an efficiency of 80% to hot water systems that replace an electrical boiler (see Fig. 11).

CO_2 abatement through solar thermal energy approx. 1.5 Gt up to 2030

Over the entire period 2006 – 2030 we expect the average annual growth rate of newly installed global capacity of solar collector systems to reach 23% (see Fig. 16). Based on these assumptions, the CO_2 reduction would come to roughly 1.5 Gt CO_2 in 2030, taking our estimate of around 3900 TWh_{th} solar thermal power production.

CSP systems:

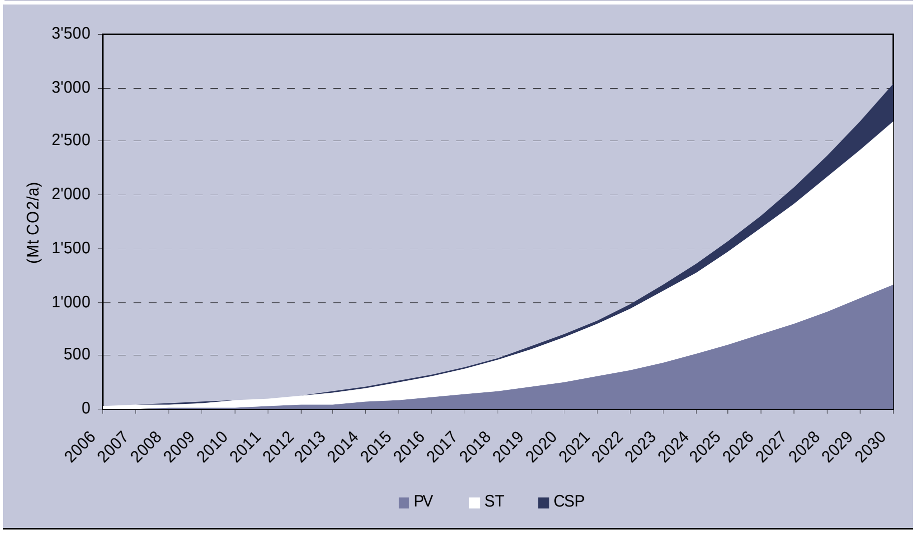
The average annual energy yields per square metre are very high compared with other technologies, because these systems tend to be installed exclusively in sun-belt regions. In the south of Spain, daily radiation from the sun is around 2300 kWh/m^2*a, and in Egypt it can be as high as 2800 kWh/m^2*a. For our calculations we used an average value of 2500 kWh/m^2*a. If equipped with storage tanks as well, the more modern systems will be able to increase their output to 3500 kWh/kW by 2030. To estimate the CO_2 savings we assume, as with photovoltaics, a global average reduction in CO_2 emissions of 0.6 kg CO_2/kWh.

CO_2 abatement through CSP systems approx. 0.25 Gt by 2030

Over the entire period 2006 – 2030 we expect the average annual growth rate of newly installed global capacity of CSP systems to reach 40%. Based on these assumptions, the CO_2 abatement up to 2030 would come to roughly 0.34 Gt CO_2 from 570 TWh of electricity generated.

[24] Solar Heat Worldwide, Markets and Contributions to the Energy Supply 2005, IEA-SHC, Edition 2007

Fig. 16: Estimated CO_2 abatement through solar energy



Source: Bank Sarasin 2007

Solar energy can prevent 3Gt CO_2 or approx. 0.8 Gt C by 2030

The total reduction achieved from all solar energy applications by 2030 could therefore amount to approximately 3 Gt CO_2. The bulk of the savings (50%) comes from heat production from solar collectors, 39% from electricity production by PV systems and 11% from CSP systems. In terms of carbon, this is equivalent to roughly 0.8 Gt C, which means in 2030 solar energy can contribute 80% of one of the seven 1 Gt C/a wedges needed to stabilise the CO_2 level in the atmosphere.

CO_2 abatement costs for individual solar technologies

The other decisive factor apart from the CO_2 reduction potential is how high the costs are for the CO_2 reduction achieved through solar energy. This is particularly important when comparing other CO_2 abatement options as part of a cost-efficient and overall economic strategy for cutting CO_2 emissions.

The costs result from:

1. the cost of generating each kWh of electricity or heat, and their development over time (cost degression, technical advances and economies of scale) and

2. the quantity of CO_2 prevented for each kWh of electricity or heat (see above).

Photovoltaics:

Average annual cost savings of 5% expected

To calculate the electricity generation costs for photovoltaics, we take a standard 25 kW solar energy system with a 2006 price of 5000 EUR/kWp and a service life of 25 years. Due to technical advances and economies of scale, the cost of PV systems will drop significantly in future. We assume an annual cost reduction rate of 5% up to 2020, which corresponds to the current degression in Germany's feed-in tariffs. After that the annual cost saving eases to 4%. The maintenance costs are 0.04 EUR/kWh initially and are reduced by 2% every year. We assume an interest rate of 5% for the capital costs over the entire period.

When comparing costs, we basically assume that the PV system replaces peak-load electricity. This is particularly the case in hot regions, where peak loads are during the afternoon when the air conditioning is switched on. The cost of generating peakload power on the mains grid was set at 0.151 EUR/kWh (2006) (incl. transport and distribution costs, T&D of 0.055 EUR/kWh). We also assumed 2% annual cost inflation up to 2030 due to rising fuel prices as fossil fuels become scarcer and CO_2 emission certificates become more expensive.

Fig. 17: CO_2 abatement costs for photovoltaics from 2006 to 2030

Situation for photovoltaics	2006	2010	2020	2030
Cumulative PV capacity in service (GWp)*	6	26	359	1'637
Total CO_2 reduction (Mt/a)	4	18	254	1'158
Price for installed system (EUR/kWp)	5'000	4'073	2'464	1'638
Average PV production costs (EUR/kWh)**	0.34	0.28	0.19	0.14
Mains power production costs, peakload power (EUR/kWh)**	0.15	0.16	0.18	0.21
Additional PV costs (EUR/kWh)	0.19	0.13	0.01	-0.07
CO_2-Reduction (kg CO_2/kWh)	0.57	0.58	0.59	0.59
Net abatement costs (EUR/t CO_2)	328	216	15	-117

* adjusted by deducting the capacity installed 25 years ago; ** including transport & distribution costs of 0.027 EUR/kWh for PV and 0.055 EUR/kWh for conventional energy production; Source: www.vattenfall.com – Curbing Climate Change 2006

PV expected to achieve cost parity with peakload power in 2021

Based on these assumptions, the extra cost of PV electricity compared with peakload electricity from gas-fuelled power stations currently amounts to approximately 19 eurocents/kWh (Fig. 17). In the next 15 years, however, the costs of producing solar energy will drop in the area of producing peakload power. At the same time CO_2 abatement costs also decrease from around 328 EUR/t CO_2 in 2006 to around 15 EUR/t CO_2 in 2020. Under these assumptions, parity will be achieved with peakload power one year later, so CO_2 prevention costs will drop to zero by then. This analysis of average electricity costs is more in tune with the perspective of an electricity provider than the end consumer. If this cost parity is achieved, photovoltaics can offer utility companies an attractive option for decentralised production of peakload power. From the end consumer’s viewpoint, PV electricity may of course become competitive with conventional electricity prices much sooner in southern regions.

Solar collectors:

Annual cost saving potential of 2%

When calculating the heat production costs for solar thermal energy, we assume an average system price 2006 of 1300 EUR/kW_{th} and a service life of 20 years. Through savings produced by economies of scale and certain technological advances, the costs for solar thermal systems can only be marginally reduced in future. In fact rising raw material prices are more likely to push costs up. As a result, an average annual cost reduction rate of only 2% can be achieved. Maintenance costs, on the other hand, only amount to approximately 0.01 EUR/kWh_{th} while we assume an interest rate of 5% for the capital costs up to 2030.

CO_2 abatement costs currently 104 EUR/ t CO_2

When comparing costs, we basically assume that the solar thermal system replaces heating oil. Since despite everything a combined system still requires a supplementary heating source (oil, gas, pellets, electricity or heat pump), our cost comparison only takes into consideration the quantity of fuel replaced by solar heat, but not the investment costs or system costs for the supplementary heating or hot water system. As with CO_2 reduction, heating oil is used as a comparison base when estimating costs. A heating oil price of 55 EUR/100l is assumed for 2006. With an energy content of 10.2 kWh/l of heating oil and heating efficiency of 80%, the fuel costs work out at 0.07 EUR/kWh and the heat production costs at 0.11 EUR/kWh_{th}.

Fig. 18: CO_2 abatement costs for solar collectors from 2006 to 2030

Situation for solar collectors	2006	2010	2020	2030
Cumulative ST capacity in service (GWth)*	96	215	1'492	5'539
Total CO_2 reduction (Mt/a)	27	60	418	1'551
Price for ST system (EUR/kWth)	1300	1241	1138	1071
Full ST production costs (EUR/kWhth)	0.15	0.14	0.13	0.12
Heat production costs for heating oil (EUR/kWhth)	0.11	0.12	0.14	0.17
Additional ST costs (EUR/kWh)	0.04	0.03	-0.01	-0.05
Net CO_2 reduction (kg CO_2/kWh)	0.38	0.39	0.39	0.39
Net abatement costs (EUR/t CO_2)	104	67.3	-21	-123

* Adjusted by deducting the capacity installed 20 years ago in each case

Parity of CO_2 abatement costs achieved in 2018

We assume that heating oil costs rise by 3% p.a. up to 2030. It is of course very difficult to predict energy price trends. Inflation could also rise far more swiftly. The net CO_2 abatement costs will achieve parity by 2018.

CSP systems:

CSP cost saving potential is 3% p.a

With CSP systems, the sun's radiation is harnessed and the energy concentrated, using various technologies, in order to heat up a medium that then drives a conventional steam turbine to produce the electricity from a generator. This technique is generally referred to as Concentrating Solar Power, or CSP. To calculate the electricity production costs for a CSP system, we assume a 100 MW parabolic trough system with no storage facility. This type of system cost around 3500 EUR/kW in 2006 and has an expected service life of 25 years. Due to technical advances and economies of scale, the cost of CSP systems will drop in future. We assume an average annual cost reduction rate of 3%. The maintenance costs of 0.02 EUR/kWh and the 5% interest rate for capital costs apply over the entire period. We also assume that electricity production costs will increase by 2% p.a. up to 2030.

CSP plants achieve cost parity by 2021

When comparing costs, we basically assume that the CSP system replaces baseload power. A CSP system can supply electricity for around 18 hours, especially when used in conjunction with a suitable energy storage facility. The cost of generating baseload power on the mains grid was set at 0.10 EUR/kWh (2006) (incl. transport and distribution costs, T&D of 0.055 EUR/kWh; same as for the CSP system). We also assumed an annual increase of 2% up to 2030 as a result of rising fuel prices. The additional costs associated with CSP systems are even now only 0.07EUR/kWh higher than the cost of generating baseload electricity. As far as costs are concerned, these systems will become fully competitive from 2021 onwards (Fig. 19).

Fig. 19: CO_2 abatement costs for CSP systems from 2006 to 2030

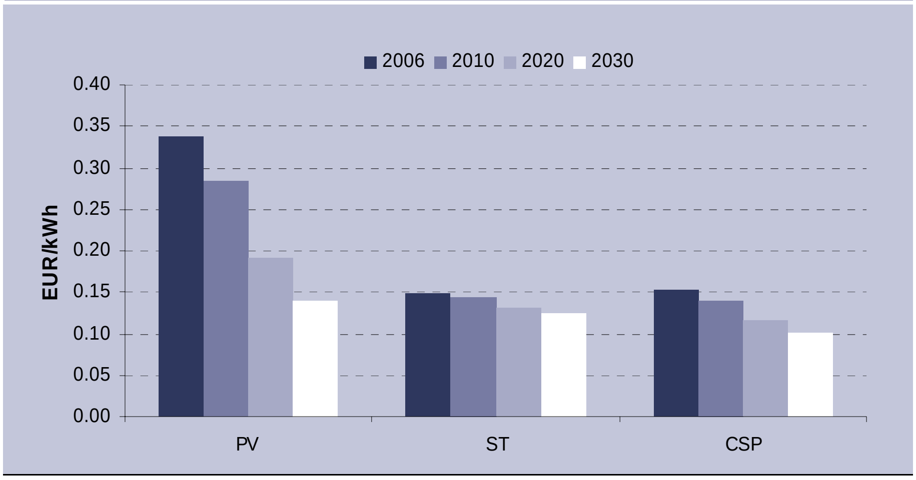
Situation for CSP	**2006**	**2010**	**2020**	**2030**
Cumulative CSP capacity in service (GW)	0.5	2.5	17	164
Total CO_2 reduction (Mt/a)	0.8	3.9	31	340
Price of CSP system (EUR/kW)	3500	2656	1959	1444
Full CSP production costs (EUR/kWh)*	0.17	0.14	0.12	0.10
Mains power production costs, baseload power (EUR/kWh)*	0.10	0.10	0.11	0.13
Additional costs for CSP electricity (EUR/kWh)	0.07	0.04	0.00	-0.03
Net CO_2 reduction (kg CO_2/kWh)	0.575	0.585	0.59	0.59
Net CO_2 abatement costs (EUR/t CO_2)	115	62	4	-43

* Including transport & distribution costs of 0.055 EUR/kWh (source: www.vattenfall.com – Curbing Climate Change 2006)

Cost saving potential: PV -58%; ST -16%; CSP -38%

An analysis of trends in electricity production costs over time highlights the differences in the way these various solar technologies are expected to grow. Photovoltaics offers enormous cost reduction potential. It will be able to slash its 2006 production costs from 0.34 EUR in 2006 to 0.14 EUR/kWh in 2030, a reduction of around 58%. Photovoltaics should therefore be able to match peak-load electricity production costs of 0.19 EUR by 2022 onwards. The relevant cost reduction potential for solar thermal power and CSP is much lower over the same period, at 16% and 38% respectively. However, their production costs per kilowatt hour are already very low. But the benchmark is not the same either. We are comparing solar thermal power with an oil-fired heating system with costs running at 0.11 EUR/kWh in 2006. The costs of solar thermal power are approximately 30% higher than this at the moment. By 2030 the production costs will have fallen significantly and should be able to compete with conventional heating by around 2018 (Fig. 20).

Fig. 20: Electricity/heat production costs from 2006 to 2030



Source: Bank Sarasin 2007

The production costs of large-scale solar thermal power stations, currently 0.17 EUR/kWh, are roughly 70% higher than conventional baseload electricity at 0.10 EUR/kWh. This includes a fixed proportion of transport and distribution costs of 0.055 EUR/kWh for both types of power station. The cost reduction for CSP is around 38% by 2030, making these systems competitive as of 2021.

Conclusions

A number of technical possibilities exist for switching to low-carbon energy production, and many of these new technologies already enjoy high annual growth rates. At the moment, the individual forms of solar energy are still more expensive than traditional energy production. Their production costs are still much higher than the cost of producing mains power.

CSP technology makes smallest contribution to CO_2 abatement, despite a growth rate of 40% p.a. (2006-30)

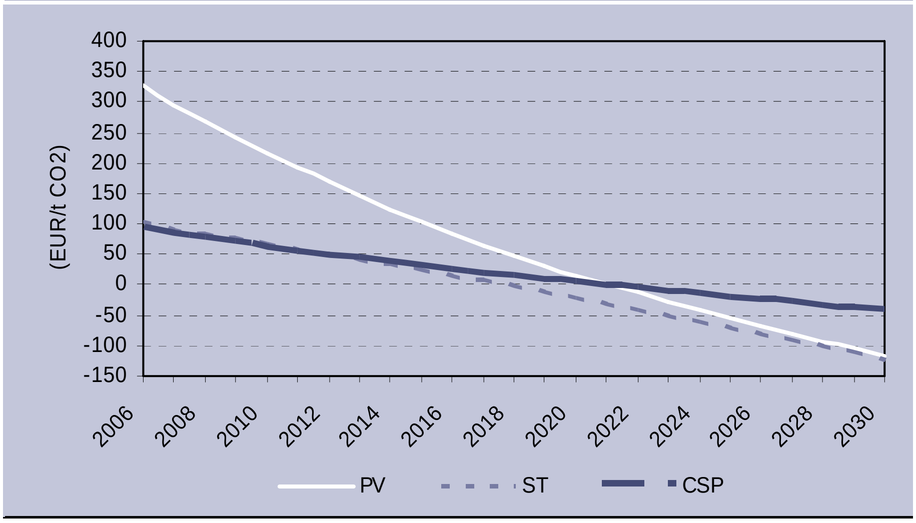
If we compare the individual production costs with the relevant contributions to reducing CO_2, the more competitive costs associated with solar thermal power are also reflected in the significant contribution it makes to reducing CO_2. Photovoltaics is certainly becoming more and more important as costs fall, and if prices are sufficiently attractive, growth rates could potentially be far higher from 2015 onwards. At first glance, the small contribution made by CSP technology to reducing CO_2 seems very surprising. This is despite CSP enjoying the highest average annual growth rate of 40% (06 -30), compared with photovoltaics (22%), and solar thermal power (15%). CSP technology has the lowest starting point of approximately 500 MW of total installed capacity. This technology has yet to prove itself with the new plants that have recently come on stream before a breakthrough can occur. Since a CSP system feeds its electricity into the mains grid, suitable locations are also limited, or require appropriate investment to expand the power transmission infrastructure. Particularly given the suitability of CSP systems for producing baseload electricity, we think this technology has significant development potential, especially if electricity providers discover CSP as a viable alternative to their conventional power stations.

Solar energy could make a significant contribution to stabilising CO_2 levels in the atmosphere up to 2030

The CO_2 reductions shown in Fig. 16 represent an annual decrease of 3 Gt of CO_2 up to 2030. This is equivalent to approximately 0.8 Gt of carbon. This clearly demonstrates that taken as a whole, solar energy technologies can make a significant contribution to stabilising CO_2 levels in the atmosphere, and what's more without any additional costs as of 2018 (see Fig. 21). This once again confirms the enormous cost-saving potential presented by solar power.

At present the net CO2 abatement costs for all solar technologies are significantly higher than the maximum price per tonne of CO_2 of 30-40EUR specified for Phase II of European CO_2 trading. Photovoltaics is currently still a very expensive strategy for reducing CO_2, costing 328 EUR/t CO_2. Costs are already lower for solar thermal power (104 EUR/t CO_2) and CSP systems (115 EUR/t CO_2).

Fig. 21: Development of net CO_2 abatement costs from 2006 to 2030



Source: Bank Sarasin 2007

The reported results are based on many different assumptions which inevitably carry an element of uncertainty. But the transparent methodology makes it simple to modify any parameter and visualise the impact on the final result.

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