The Institute for Energy provides scientific and technical support for the conception, development, implementation and monitoring of community policies related to energy. Special emphasis is given to the security of energy supply and to sustainable and safe energy production.

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European Commission
Joint Research Centre
Institute for Energy

**Contact information**
Address:
Via Enrico Fermi
TP 45
21027 Ispra (VA)
Italy
E-mail: arnulf.jaeger-waldau@ec.europa.eu
Tel.: +39 0332 789119
Fax: +39 0332 789268
http://ie.jrc.ec.europa.eu
http://www.jrc.ec.europa.eu
PV Status Report 2009

Research, Solar Cell Production and Market Implementation of Photovoltaics

August 2009

Arnulf Jäger-Waldau
European Commission, DG Joint Research Centre,
Institute for Energy, Renewable Energy Unit
Via Enrico Fermi; TP 450 I – 21027 Ispra (VA), Italia
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JRC 53664

EUR 24027 EN
ISSN 1831-4155
DOI 10.2788/22576

The report is online available at:
http://re.jrc.ec.europa.eu/refsys/

Luxembourg: Office for Official Publications of the European Union

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Front cover: Artwork by Jennifer Rundle
Layout/Typography: Sailer Design Communication, Meersburg, Germany
Printed in Belgium
Spiking oil prices at $147.27 per barrel in July 2008 and speculations when the oil price will exceed $200 per barrel have already become a reality. The enormous price fluctuations of oil prices during the last 12 months due to the volatility of the financial markets and economic turmoil, have highlighted our strong dependence on oil and have added an additional argument for the introduction of renewable energies: minimisation of price volatility risks.

The Gas Crisis at the beginning of 2006, the interruptions of the gas supply in the summer of 2008 and early 2009 have demonstrated that Europe is highly vulnerable with respect to its total energy supply. A possible solution is the diversification of supply countries, as well as the diversification of energy sources including renewable energies and Photovoltaics.

In June 2009, the new European Directive on the “Promotion of the Use of Energy from Renewable Sources” went into force and does not only set mandatory targets for the Member States in 2020, but also gives a trajectory how to reach it. The aim of the Directive is to provide the necessary measures for Europe to reduce its green-house gas emissions by 20% in 2020 in order to support the world-wide stabilisation of the atmospheric greenhouse gases in the 450 to 550 ppm range.

Photovoltaics is a key technology option to realise the shift to a decarbonised energy supply. The solar resources in Europe and world wide are abundant and cannot be monopolised by one country. Regardless for what reasons and how fast the oil price and energy prices increase in the future, Photovoltaics and other renewable energies are the only ones to offer a reduction of prices rather than an increase in the future.

As a response to the economic crisis, most of the G20 countries have designed economic recovery packages which include “green stimulus” measures. However, compared to the new Chinese Energy Revitalisation Plan under discussion, the pledged investments in green energy are marginal. If no changes are made, China which now strongly supports its renewable energy industry, will emerge even stronger after the current financial crisis.

In 2008, the Photovoltaic industry production almost doubled and reached a world-wide production volume of 7.3 GWp of Photovoltaic modules. Yearly growth rates over the last decade were in average more than 40%, which makes Photovoltaics one of the fastest growing industries at present. Business analysts predict the market volume to increase to €40 billion in 2010 and expect lower prices for consumers. The trend that thin-film Photovoltaics grew faster than the overall PV market continued in 2008.

The Eighth Edition of the “PV Status Report” tries to give an overview about the current activities regarding Research, Manufacturing and Market Implementation. I am aware that not every country and development is treated with the same attention, but this would go beyond the scope of this report. Nevertheless, I hope that this report will provide a useful overview about the situation world-wide. Any additional information is highly welcome and will be used for the update of the report.

The opinion given in this report is based on the current information available to the author, and does not reflect the opinion of the European Commission.

Ispra, August 2009

Arnulf Jäger-Waldau
European Commission
Joint Research Centre; Renewable Energy Unit
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Production data for the global cell production\(^1\) in 2008 vary between 6.9 GW and 8 GW. The significant uncertainty in the data for 2008 is due to an overheated market, as well as the fact that some companies report shipment figures, whereas others report production figures. In addition, the difficult economic conditions led to a decreased willingness to report confidential company data. Nevertheless, the figures show a significant growth of the production and an easing of the tight silicon supply situation. However, the delay of a number of silicon expansion projects might lead to a tight supply situation again, if markets recover faster than the silicon expansion takes place. Our own data, collected from various companies and colleagues was then compared to various data sources thus led to an estimate of 7.35 GW (Fig. 1), representing a production growth of about 80% compared to 2007.

Again, both Chinese and Taiwanese production increased over-proportionally, keeping the PRC in the top rank with about 2.4 GW followed by Europe with 1.9 GW, Japan with 1.2 GW and Taiwan with 0.8 GW. In terms of production, Q-cells (DE) was N° 1 (570 MW), followed by Suntech (PRC) with 550 MW, First Solar (US/DE/Malaysia) 503 MW and Sharp (JP) 470 MW. However, in terms of shipments, the order was slightly revised, N° 1 Q-cells (DE) 570 MW, followed by Suntech (PRC) with 497 MW, Sharp (JP) 458 MW and First Solar (US/DE/Malaysia) with 435 MW [Min 2009].

\(^1\) Solar cell production capacities mean:
- In the case of wafer silicon based solar cells only the cells
- In the case of thin films, the complete integrated module
- Only those companies which actually produce the active circuit (solar cell) are counted
- Companies which purchase these circuits and make cells are not counted.
This rapid increase of the production also led to a massive increase of inventory stocks. This can be observed if one looks at the development of the figures reported for shipments to first point of sale (5.5 GW) [Min 2009] and the global PV Market estimates which range between 5.5 GW and 6 GW [Epi 2009, Fra 2009].

Since 2003, total PV production increased almost 10 fold with annual growth rates between 40% and 80%, whereas the thin film segment – starting from a very low level – grew in average by over 90%. In 2008 shipments to point of first sale increased to 750 MW or 14%. The high growth rate of thin film production and the increase of the total production share indicate that the thin film technology is gaining more and more acceptance in the markets. Equally competitive technologies are amorphous/micromorph Silicon, CdTe and Cu(In,Ga)(S,Se)2 thin films. In addition, more and more PV manufacturers are diversifying their production portfolio and add thin film production to the wafer based one. It should be noted that the current thin film market leader First Solar will reach an annual production capacity of more than 1 GW by the end of 2009. Sharp (Japan), Showa Shell Sekiyu (Japan) and Best Solar (PRC) had announced they would increase their thin film production to at least 1 GW capacity to be operational in 2010 [Bes 2008, Sha 2007] and 2011 [Sho 2008] respectively, but in the meantime their expansion speed has slowed down. Despite this development, a thin film market share of 20 to 25% in 2010 seems not to be unrealistic as a number of other thin film manufacturers are aiming at 500 MW production capacities in that time frame.

Public traded companies manufacturing solar products, or offering related services, have attracted a growing number of private and institutional investors. In 2008 worldwide new investments into the renewable energy and energy efficiency sectors increased to a record US $ 155 billion (€ 110 billion), up 5% from 2007, but the second half of efficiency sectors increased to a record US $ 155 billion new investments into the renewable energy and energy efficiency measures. However, analysts predict that only about 15% or less will be spent in 2009, whereas two thirds of these funds will be spent in 2010 and 2011.

The number of consulting companies and financial institutions offering market studies and investment opportunities has considerably increased in the last few years and business analysts are very confident that despite raising interest rates, the Photovoltaics sector is in a healthy long term condition. Following the stock market decline, as a result of the financial turmoil, the PPVX3 (Photon Photovoltaic stock index) declined to 2,095 points at the end of 2008. Between January and 7 August 2009 the index has increased by 12.9% to 2,552 points and the market capitalisation of the 30-PPVX companies4 was € 32.6 billion. It is expected that the arrival of the “green stimulus” money from governments aimed to help relieve the effect of the recession will further stimulate the PV markets. Since September 2008, the major economies have announced about US $ 185 billion (€ 132 billion) of recovery funds aimed at renewable energies or energy efficiency measures. However, analysts predict that only about 15% or less will be spent in 2009, whereas two thirds of these funds will be spent in 2010 and 2011.

New investments in solar power grew again surpassing bioenergy and second only to wind with US $ 33.5 billion (€ 23.9 billion) or 21.6% of new capital in 2008 [UNEP 2009]. Solar power continued to be the fastest growing sector for new investments: acquisition transactions US $ 11 billion (€ 7.86 billion), venture capital (VC) and private equity (PE) US $ 5.5 billion (€ 3.93 billion), public market investments US $ 6.4 billion (€ 4.57 billion).

Market predictions for the 2010 PV market vary between 6.8 GW (Navigant conservative scenario), 7 to 10 GW (EPIA policy driven scenario, EuPD, Bank Sarasin, LBBW) and 17 GW (Photon Consulting). Massive capacity increases are underway or announced and if all of them are realised, the worldwide production capacity for solar cells would exceed 38 GW at the end of in 2010. This indicates that even with the most optimistic market growth expectations, the planned capacity increases are way above the market growth. The consequence would be a quite low utilisation rate and consequently an accelerated shift from the demand-driven markets of the last years to an oversupplied market which will increase the pressure on the margins. Such a development will accelerate the consolidation of the Photovoltaics industry and spur more mergers and acquisitions.

The current solar cell technologies are well established and provide a reliable product, with sufficient efficiency and energy output for at least 25 years of lifetime. This reliability, the increasing potential of electricity interruption from grid overloads, as well as the rise of electricity prices from conventional energy sources, add to the attractiveness of Photovoltaic systems.

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2 Exchange rate: 1 € = 1.40 US$
About 85% of the current production uses wafer-based crystalline silicon technology. Up to now the main advantage of this technology was that complete production lines could be bought, installed and be up and producing within a relatively short time-frame. This predictable production start-up scenario constitutes a low-risk placement with calculable return on investments. However, the last shortage in silicon feedstock and the market entry of companies offering turn-key production lines for thin film solar cells led to a massive expansion of investments into thin film capacities. More than 150 companies are involved in the thin film solar cell production process ranging from R&D activities to major manufacturing plants.

The past shortage in silicon feedstock, the relative slow response of the established silicon producers and the accelerated expansion of production capacities led to the market entry of new potential silicon producers.

The following developments can be observed at the moment:

■ Silicon producers are in the process of increasing their production capacities, which will ease the pressure on the supply side within the next years. However, a number of expansion projects have been delayed due to the financial constraints and current market situation.

■ New silicon producers are entering the market, and in the process of finalising their business plans or are already constructing new production facilities. However, due to the current restricted financial opportunities a number of projects are on hold or cancelled.

■ PV companies accelerate the move to thinner silicon wafers and higher efficient solar cells in order to save on the silicon demand per Wp.

■ Significant expansions of thin film production capacities of existing manufacturers are under way and a large number of new manufacturers try to enter the market to supply the growing demand for PV modules. Despite the scale back of expansion plans by some companies, the number of new entrants and their planned capacities are still increasing the overall announced capacity. If all announced thin film production capacities are realised, more than 11 GW production capacities could be reached by 2010. This is an increase of about 10% compared to the announcements made in the autumn of last year.

Projected silicon production capacities available for solar in 2010 vary between 99,500 metric tons [Pvn 2008] and 245,000 metric tons [EuP 2008]. The possible solar cell production will in addition depend on the material use per Wp. Material consumption could decrease from the current 10 g/Wp down to 8 g/Wp, but this might not be achieved by all manufacturers.

Similar to other technology areas, new products will enter the market, enabling further cost reduction. Concentrating Photovoltaics (CPV) is an emerging market with approximately 17 MW cumulative installed capacity at the end of 2008. In addition, Dye-cells are getting ready to enter the market as well. The growth of these technologies is accelerated by the positive development of the PV market as a whole. It is interesting to note that not only new players are entering into thin film production, but also established silicon-based PV cell manufacturers diversify into thin film PV.

It can be concluded that in order to maintain the extremely high growth rate of the Photovoltaic industry, different pathways have to be pursued at the same time:

■ Drastic increase of solar grade silicon production capacities;

■ Accelerated reduction of material consumption per silicon solar cell and Wp, e.g. higher efficiencies, thinner wafers, less wafering losses, etc.;

■ Accelerated introduction of thin film solar cell technologies and CPV into the market as well as capacity growth rates above the normal trend.

Further cost reduction will depend not only on the scale-up benefits, but also on the cost of the encapsulation system, if module efficiency remains limited to below 15%, stimulating strong demand for very low area-proportional costs.
The Photovoltaic world market grew in terms of production by more than 80% in 2008 to approximately 7.35 GW. The market for installed systems about doubled and the current estimates are between 5.6 and 6 GW, as reported by various consultancies (Fig.2). One could guess that this represents mostly the grid connected Photovoltaic market. To what extent the off-grid and consumer product markets are included is unclear. The difference of roughly 1.3 to 1.75 GW could therefore be explained as a combination of unaccounted off-grid installations (approx. 100 MW off-grid rural, approx. 100 MW communication/signals, approx. 80 MW off-grid commercial), consumer products (ca. 100 MW) and cells/modules in stock.

The impressive growth in 2008 is mainly due to the exceptional development in the Spanish market, which almost increased five-fold from 560 MW in 2007 to 2.5 – 2.7 GW in
2008 [Epi 2009, Sys 2009]. The second largest and most stable market was Germany with 1.5 GW followed by the US (342 MW), South Korea (282 MW), Italy (258 MW) and Japan (230 MW). The Photovoltaic Energy Barometer reported that Europe had a cumulative installed PV system capacity of 9.5 GW in 2008.

Despite the fact that the European PV production grew again by over 80% and reached 1.9 GW, the exceptional market situation in Spain, the size of the German and the rapidly developing Italian market, the promising developments in Belgium, the Czech Republic (51 MW), France (46 MW) and Portugal (50 MW) did not change the role of Europe as a net importer of solar cells and/or modules. The ongoing capacity expansions and the cap in the Spanish market might change this in the future.

The third largest market was the USA with 342 MW of PV installations, 292 MW grid-connected [Sei 2009]. California, New Jersey and Colorado account for more than 75% of the US grid-connected PV market. After more than a year of political debate the US Senate finally voted to extend the tax credits for solar and other renewable energies on 23 September 2008. On 3 October 2008, following weeks of contentious negotiations between the House and Senate, Congress approved and the President signed into law the “Energy Improvement and Extension Act of 2008” as part of H.R. 1424, the “Emergency Economic Stabilization Act of 2008”.

On 27 May 2009, President Obama announced to spend over $ 467 million from the American Reinvestment and Recovery Act to expand and accelerate the development, deployment, and use of geothermal and solar energy throughout the United States. The Department of Energy (DOE) will provide $ 117.6 million in Recovery Act funding to accelerate the widespread commercialisation of solar energy technologies across America. $ 51.5 million will go directly for Photovoltaic Technology Development and $ 40.5 million will be spent on Solar Energy Deployment, where projects will focus on non-technical barriers to solar energy deployment.

There is no single market for PV in the United States, but a conglomeration of regional markets and special applications for which PV offers the most cost-effective solution. In 2005 the cumulative installed capacity of grid-connected PV systems surpassed that of off-grid systems. Since 2002 the grid-connected market has been growing much faster, thanks to a wide range of “buy-down” programmes, sponsored either by States or utilities.

South Korea became the fourth largest PV market in 2008. At the end of 2006 the cumulative installed capacity of Photovoltaic electricity systems was only in the range of 25 MW. In 2007 about 45 MW were installed and in 2008 the market surpassed the estimated 75 to 80 MW by far, with 282 MW of new installations [Kim 2009]. The driver for this development is the Government’s goal to increase the share of New and Renewable Energy Sources (NRES) to 5% by 2011. For Photovoltaics, a goal of 1.3 GW cumulative installed Photovoltaic electricity generation capacity by 2012 and 4 GW by 2020 was set.

In January 2009, the Korean Government has announced the third National Renewable Energy Plan, under which renewable energy sources will steadily increase their share of the energy mix between now and 2030. The plan covers such areas as investment, infrastructure, technology development and programmes to promote renewable energy.

The new plan calls for a Renewable Energies share of 4.3% in 2015, 6.1% in 2020 and 11% in 2030.

To reach this target, South Korea had introduced an attractive feed-in tariff for 15 years along with investment grants up to 60%. From October 2008 to 2011 the following feed-in tariffs are valid (Table 1).

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Table 1: Korean Feed-in Tarifs [Kim 2009]
Fixed Price in Korean Won/kWh (€/kWh)

<table>
<thead>
<tr>
<th>Until</th>
<th>Period</th>
<th>&lt;30kW</th>
<th>&gt;30 kW</th>
</tr>
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<tbody>
<tr>
<td>30 Sept. 2008</td>
<td>15 years</td>
<td>711.25 (€ 0.44)</td>
<td>677.38 (€ 0.42)</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Until</th>
<th>Period</th>
<th>&lt;30kW</th>
<th>30 – 200 kW</th>
<th>200 kW – 1 MW</th>
<th>1 MW – 3 MW</th>
<th>&gt;3 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Oct. 2008 – 2009</td>
<td>15 years</td>
<td>646.96 (0.40)</td>
<td>620.41 (0.39)</td>
<td>590.87 (0.37)</td>
<td>561.33 (0.35)</td>
<td>472.7 (0.30)</td>
</tr>
<tr>
<td>20 years</td>
<td></td>
<td>589.64 (0.37)</td>
<td>562.84 (0.35)</td>
<td>536.04 (0.34)</td>
<td>509.24 (0.32)</td>
<td>428.83 (0.27)</td>
</tr>
</tbody>
</table>

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\( \text{Exchange rate: } 1 \text{ €} = 1600 \text{ KRW} \)
From 2012 on it is planned to substitute the tariffs by a Renewable Portfolio Standard. In the new tariff scheme it is possible to choose between 15 years guarantee and a higher kWh price and a 20 years guarantee and a somewhat lower kWh price. The previous 100 MW cap was increased to 500 MW and if it is not reached in 2009 the fixed prices applicable for new systems in 2010 will be announced later. However, the cumulative installed capacity at the end of 2007 was 78 MW. In January 2008, 46 MW of installed capacity was under the cap scheme and more than 560 MW were already under planning or construction. The Korean Government aims to equip 100,000 houses and 70,000 public/commercial buildings with PV systems by 2012. An interesting aspect is that some of the larger projects will qualify for Clean Development Mechanism (CDM) credits, allowing for trading of Certified Emission Reductions (CER) under the Kyoto Protocol.

After two years of decline, the Japanese market rebounded slightly and reached 230 MW of new installations, 9% higher than in 2007, but still 21% lower than in 2006 and 2007. To change this situation, the Japanese Ministry for Economy, Trade and Industry (METI) proposed a new investment incentive scheme which was introduced by the Japanese Government, starting in January 2009. The allocated budget for the last months of FY2008 (January – March 2009) and FY2009 would allow the installation of more than 100,000 systems or 400 MW.

METI started to review the Renewable Portfolio Standard (RPS) Law in order to prepare the introduction of a new PV power purchase programme, which should allow the purchase of “excess” electricity from PV systems at a higher rate and it is planned to introduce this measure for FY2010. The “Japanese Recovery Plan” with its three pillars 1) Low-carbon revolution, 2) Healthy long life and 3) Exert Attractiveness includes the specific project “Plan to become the world’s leading PV & energy-saving nation” and calls for a drastic acceleration of the introduction of PV power generation. The goal is an approximately twenty-fold increase of the cumulative installed PV capacity by 2020.

In addition to the National Government, Local Government and Utilities have announced plans as well. The Tokyo Metropolitan Government implemented a plan to install 1 GW within the next 10 years and gives an investment support for the installation of residential PV systems in FY 2009 and FY2010. Other prefectures and cities have also announced implementation plans and are offering additional investment incentives as well.

At the end of 2008, total cumulative installed capacity in 2008 stands at 2.15 GW, less than half of the original 4.8 GW goal for 2010 [Ohi 2009, Epi 2009]. Despite a production increase of 31% in 2008 compared to 2007, the world market share of Photovoltaic devices manufactured in Japan further decreased from 23% to 17%.

The number of Japanese companies amongst the Top Ten was three, equal to those from PR China (Fig. 3).

The rapid expansion of solar cell manufacturing capacities and production volume in the People’s Republic of China and Taiwan is not yet reflected in a significant size of the respective home markets.

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Fig. 3: Top 10 Photovoltaic companies 2008

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* Exchange rate: 1 € = 9.5 RMB
Despite the fact that the Chinese PV market more than doubled in 2008 to 45 MW, the home market is still less than 2% of total Photovoltaic production. This situation might change because China’s RMB 4 trillion stimulus package, which was announced in early March 2009, includes RMB 210 billion (€ 22 billion) for green energy programmes. On 23 March 2009 the Chinese Ministry of Finance and Ministry of Housing and Urban-Rural Development [Mof 2009] announced a solar subsidy programme which immediately went into effect. For 2009 the subsidy will be 20 RMB/Wp (2.10 €/Wp) installed. The document neither mentions a cap on individual installations nor a cap for the total market. It was suggested that 70% of the incentives budget would be transferred to the Provincial Finance Ministries.

Analysts believe that these measures will accelerate the Chinese domestic market. For 2009 a doubling, or even tripling of the market seems possible as a starting point for the development of a GW size market from 2012 on. China is now aiming for 2 GW solar capacity in 2011 and in July 2009 under the new energy stimulus plan China revised its 2020 targets for installed solar capacity to 20 GW. In addition, the National Energy Administration (NEA) has set a subsidised price for solar power at 1.09 RMB/kWh (0.115 €/kWh).

To promote the solar energy industry the Taiwanese Government decided to subsidise manufacturers engaging in R&D and will offer incentives to consumers that use solar energy. About a dozen manufacturers expressed the intention to invest in fabricating thin films for solar cells and eight of them will set up their own plants to process the products. Moreover, the Industrial Technology Research Institute (ITRI), a Government-backed research organisation, is going to import advanced foreign technology for local manufacturers.

On 12 June 2009, the Legislative Yuan passed the “Renewable Energy Development Statute“, which aims to increase the total renewable electricity capacity by 6.5 GW over the next 20 years. It is expected that 1.2 GW of these new renewable capacities would come from PV.

On 1 July 2008, Prime Minister Manmohan Singh unveiled India’s first National Action Plan on Climate Change. To cope with the challenges of Climate Change India identified eight National Missions aimed to develop and use new technologies. The use of solar energy with Photovoltaics and Concentrating Solar Power (CSP) is described in the National Solar Mission (NSM). The actions for Photovoltaics in the National Solar Mission call for R&D collaboration, technology transfer and capacity building. In April 2009, the Union Government finalised the draft for the National Solar Mission. It aims to make India a global leader in solar energy and envisages an installed solar generation capacity of 20 GW by 2020, 100 GW by 2030 and 200 GW by 2050.

In April 2009, SEMI’s PV group published a White Paper where they identified the need for focused, collaborative and goal-driven R&D for Photovoltaics in India as one of the key challenges for the growth and development of PV in industry [Sem 2009]. This is a clear signal that the current support activities for the increase of production capacities and deployment are seen as insufficient to utilise the solar potential of the country. The materials and semiconductor research base in India is excellent and with proper public and private funded R&D Programmes in place, India’s academia and industry could accelerate the development and growth of the industry substantially.

At the end of 2008, most of Photovoltaic applications in India were off-grid, mainly solar lanterns, solar home systems, solar street lights and water pumping systems. Grid-connected were 33 solar Photovoltaic systems with a total capacity of approximately 2 MWp. For its eleventh Five Year Plan (2008 – 2012) India has set a target to install 50 MW grid-connected Photovoltaic systems supported by the Ministry of New and Renewable Energy with an investment subsidy and power purchase programme. Contrary to these moderate installation plans, Indian PV companies expect the PV market in India to grow to 1 – 2 GW by 2010.

Another noteworthy development is the fact that the market share of the ten largest PV manufacturers together further decreased from 80% in 2004 to 50% in 2008. This development is explained by the fact that an increasing number of solar cell manufacturers are entering the market. The most rapid expansion of production capacities can be observed at the moment in China and Taiwan, but other countries like India, Malaysia and South Korea are following the example to attract investment in the solar sector.

The announced increases of production capacities – based on a survey of more than 200 companies worldwide – again accelerated in 2008 and the first half of 2009 (Fig. 4). Only published announcements of the respective companies and no third source info were used. The cut-off date of the info used was July 2009.

This method has of course the setback that

a) not all companies announce their capacity increases in advance, and

b) that in times of financial tightening, the announcements of expansion plan scale-back are often delayed in order not to upset financial markets.

Therefore, the capacity figures just give a trend, but do not
represent final numbers. It is worthwhile to mention that despite the fact that a significant number of players have announced a slow down of their expansion, or cancelled their expansion plans for the time being, the number of new entrants into the field, notably large semiconductor or energy related companies, are overcompensating this and, at least on paper, are increasing the expected production capacities.

In addition, the assessment of all the capacity increases is rather difficult, as it is affected by the following uncertainties. The announcements of the increase in production capacity in Europe, the US or China, often lack the information about completion date compared to Japan. Because of the Japanese mentality, where it is felt that a public announcement reflects a commitment, the moral pressure to meet a given time target is higher in Japan than elsewhere, where delays are more acceptable. Not all companies announce their capacity increases in advance.

In addition, it is of high importance to note that production capacities are often announced, taking into account different operation models, such as number of shifts, operating hours per year, etc.

Announcements of the increase in production capacity do not always specify when the capacity will be fully ramped up and operational and frequently refer to the installation of the equipment only. It does not mean that the production line is really fully operational. This means, especially with new technologies, that there can be some time delay between installation of the production line and real sales of solar cells. In addition, the production capacities are not equal to sales and therefore, there is always a noticeable difference between the two figures, which cannot be avoided.

If all these ambitious plans can be realised by 2012, China will have about 32% of the worldwide production capacity of 54 GW, followed by Europe (20%), Taiwan (15%) and Japan (12%) (Fig. 4). However, it is expected that the capacity utilisation rate will further decrease from 56% in 2007 and 54% in 2008 to less than 50% in 2012.

In 2005 production of Thin-Film solar modules reached for the first time more than 100 MW per annum. Since then the **Compound Annual Growth Rate** (CAGR) of thin-film solar module production was even beyond that of the overall industry increasing the market share of thin-film products from 6% in 2005 to 10% in 2007 and 12 – 14 % in 2008. Thin-film shipments in 2008 increased by 129% compared to 2007 and the utilisation rate of thin-film capacities is 60% and somewhat higher than the overall utilisation rate of the photovoltaic industry, with 54%.

More than 150 companies are involved in the thin-film solar cell production process, ranging from R&D activities to major manufacturing plants. The first 100 MW thin-film factories became operational in 2007 and the announcements of new production capacities accelerated again in 2008. If all expansion plans are realised in time, thin-film production capacity could be 11.9 GW (vs 4.5 GW reported 2007 at the 22nd EUPVSEC in Milan) or 30% of the total 39 GW in 2010 and 20.4 GW in 2012 of a total of 54.3 GW (Fig. 5). The first thin-film factories with GW production capacity are already under construction for various thin-film technologies.

However, one should bear in mind that out of the ca. 150...
companies, which have announced their intention to increase their production capacity or start up production in the field of thin films, only one fourth have actually already produced thin film modules on a commercial scale.

For 2010 about 12 GW of thin film production capacities are announced, which is almost a doubling of the 2009 figures. Considering that the 2009 end-of-year capacity could eventually be ready for production, First Solar and Sharp together could contribute with about 2 GW, whereas the other existing producers would add about the same capacity. For that reason, 4 GW production in 2010 are considered as possible, if market conditions allow. For the remaining 2 GW there is a high uncertainty as to whether or not it can be realised in the time-frame given.

Despite the fact that only limited comparisons between the different world regions are possible, the planned cell production capacities portray some very interesting developments.

First, the technology, as well as the company distribution, varies significantly from region to region (Fig. 6). 48 companies are located in Europe, 41 in China, 25 in the US, 17 in Taiwan, 9 in Japan and 16 elsewhere. The majority of 117 companies is silicon based. The reason is probably that in the meantime there is a number of companies offering complete production lines for amorphous and/or micro-morph silicon. 30 companies will use Cu(In,Ga)(Se,S)₂ as absorber material for their thin-film solar modules, whereas 11 companies will use CdTe and 8 companies go for dye and other materials.

Concentrating Photovoltaics (CPV) is an emerging market with approximately 17 MW cumulative installed capacity at the end of 2008. There are two main tracks – either high concentration > 300 suns (HCPV) or low to medium concentration with a concentration factor of 2 to approx. 300. In order to maximise the benefits of CPV, the technology requires high Direct Normal Irradiation (DNI) and these areas have a limited geographical range – the “Sun Belt” of the Earth. The market share of CPV is still small, but an increasing number of companies are focusing on CPV. In 2008 about 10 MW of CPV were produced and market predictions for 2009 and 2010 are 30 MW and 100 MW respectively.

In the case of a continuing silicon feedstock expansion to 120,000 metric tons available for the solar industry and a material consumption decrease to 8 g/Wp, about 20 GW of solar cells could theoretically then be produced annually (15 GW silicon based and 6 GW thin films). This would be twice as much as the current optimistic market predictions forecast. Another important factor is the actual utilisation rate of the production capacities. For 2007 and 2008, the overall capacity utilisation rates of the solar cell industry with respect to shipments were given as 56% and 54% respectively by Navigant Consulting [Min 2009]. This is different from the utilisation rate with respect to production, as shipments were given with 3,061 MW and 5,492 MW by Navigant.

Second, more than 15 companies are aiming at total production capacity in the order of 1GW or more within the next five to six years. The number of those aiming at 500 MW or more in the same time-frame is above 20.

This leads to a third observation. If the large increase in production capacity is realised in China, the share on the world market...
Fig. 6: Regional and technology distribution of the thin-film production capacity increases.

The market would increase from 11.9% in 2005 to about 32% in 2012. This production capacity would be much more than the 2 GW of cumulative installed solar systems in the People’s Republic of China by 2011, as announced in July 2009. Despite the positive market development signs in China, the solar cell manufacturers in China will continue with a high export rate (98% in 2007) of their production to the growing markets in Europe, the US and developing countries.

In response to the Intergovernmental Panel on Climate Change’s (IPCC) Fourth Assessment Report “Climate Change 2007”, the European Council endorsed during its Council Meeting in Brussels on 8-9 March 2007 a binding target of a 20% share of renewable energies in the overall EU energy consumption by 2020 and a 10% binding minimum target to be achieved by all Member States for the share of Biofuels in overall EU transport petrol and diesel consumption [CEU 2007]. This target became law, when the Directive 2009/28/EC on the promotion of the use of energy from renewable energy sources was officially published on 5 June 2009 [EC 2009].

During the 23rd European Photovoltaic Solar Energy Conference and Exhibition from 1 to 5 September 2008, Anton Milner, Director of EPIA, presented the new vision of the European Photovoltaic Industry Association to produce 6 to 12% of European electricity with Photovoltaic systems in 2020. This would correspond to 210 to 420 TWh of electricity or 175 to 350 GWp installed capacity of Photovoltaic electricity systems. To realise this new vision, around 165 GW to 340 GW of new capacity have to be installed between 2009 and 2020. Installations of new Photovoltaic systems would have to increase from around 4.5 GW per annum in 2008 to 40 – 90 GW per annum in 2020. This corresponds to a CAGR (Compound Annual Growth Rate) of 26% to 33% over the next 12 years.

This would be a dramatic change from the development of the last years. Since the introduction of the German Feed-in Law in 1999, more than 80% of European PV systems were installed in Germany. The Spanish PV market grew from 14.5 MW in 2005, to about 2.7 GW in 2008. However, the prospects for 2009 are not as bright as the Spanish Government introduced a cap of 500 MW on the yearly installations, which is well below the 2008 installation figure. Since 1999, European PV production has grown on average by 50% per annum and reached almost 2 GW in 2008. The European market share rose during the same time from 20% to 25%, whereas the Chinese from 0% to more than 30%. On the contrary, the US share decreased due to a weak home market. By 2005 the Japanese market share had increased and stabilised at around 50 ± 3%, but decreased sharply to 37% in 2006, 24% in 2007 and 16% in 2008.

The European PV industry has to continue its high growth over the next years in order to maintain that level and to contribute to the new EPIA vision. This will, however, only be possible if reliable and long-term political frame conditions – not to be changed each year – are in place in Europe to enable a return on investment for the PV industry and the final consumer. One of the crucial issues is an agreement on an easy and priority access of renewable electricity to the grid all over Europe and preferably worldwide. The design of subsequent
monetary support mechanisms like feed-in tariffs, tax incentives or direct investment subsidies, should then be designed in a way that they enable the necessary capital investment and take into account the cost and market developments.

Besides this political issue, a continuous improvement of the solar cell and system technology is required. This leads to the search for new developments with respect to material use and consumption, device design, reliability and production technologies, as well as new concepts to increase overall efficiency.

Such developments are of particular interest in view of the strategic importance of solar cell production as a key technology in the 21st century, as well as for the electrification of developing countries and the fulfilment of Kyoto Targets.
3. Japan

The long-term Japanese PV research and development programmes, as well as the measures for market implementation which started in 1994, have ensured that Japan has become a leading PV nation world-wide. The principles of Japan’s Energy Policy are the 3Es:

- Security of Japanese Energy Supply (Alternatives to oil)
- Economic Efficiency (Market mechanisms)
- Harmony with Environment (Cutting CO₂ emissions on line with the Kyoto Targets)

3.1 Policies to Introduce New Energies in Japan

In earlier Status Reports, the main differences between the Japanese and European reasons for the introduction of renewable energies, as well as the history, were already described [Jäg 2004]. The current basic energy policy is based on market principles, but seeks to ensure a stable supply and environmentally-friendly production and consumption of energy at the same time [MET 2006]. The justification for the promotion of New Energies is spelled out in the goals supporting this policy:

- Promoting energy conservation measures;
- Developing and introducing diverse sources of energy;
- Ensuring a stable supply of oil;
- Basing the energy market on market principles.

The scarcity of natural conventional energy resources in Japan, the current status of mid/long-term supply of oil and the risks for a stable energy supply for Japan, as well as the need to address global environmental problems, such as reducing emissions of greenhouse gases like CO₂, increase the need to accelerate the advancement of implementation of new energy. A description of the development of the Japanese legislation and activities can be found in the 2008 PV Status Report [Jäg 2008].

In November 2008, METI published the “Action Plan for Promoting the Introduction of Solar Power Generation” [MET 2008]. This Action Plan was developed in order to support the Government’s “Action Plan for Achieving a Low-carbon Society” (approved by the Cabinet in July 2008) which set targets such as
Increase the amount of installations of solar power generation systems 10-fold by 2020 and 40-fold by 2030, and

Roughly halve the current price of the solar power generation system within three to five years.

The “Comprehensive Immediate Policy Package” (formulated by the Government and the ruling parties in August 2008) also cites the promotion of the installation of solar power generation systems in homes, businesses and public facilities as a specific measure for the radical introduction of new energy technologies in an effort to create a low-carbon society.

A range of measures are proposed within three categories:

- **Supply and demand**
  The increase in the amount of installations, the reduction in equipment prices, and the expansion of the market, should be pursued by implementing both “supply-side” measures (providing high-performance solar power generation systems at low cost) and “demand-side” measures (promoting the installation of solar power generation systems in individual sectors such as households, businesses and public facilities) in such a way as to create synergies.

- **Building an institutional infrastructure**
  Along with supply-side and demand-side assistance measures, it is essential that institutional infrastructure, including regulatory instruments, be developed in a comprehensive and unified manner. For this reason, the Government should improve institutional infrastructure in a way that facilitates smooth dissemination of solar power generation.
  An appropriate tool could be the operation of the Renewable Portfolio Standard Law (RPS Law) as a response to figures in the Outlook for Long-Term Energy Supply and Demand.

- **Consolidate the infrastructure for the solar energy-related industries, strengthen international competitiveness and support of international expansion**
  In addition to expanding the range of industries related to solar power generation, there is an urgent need to strengthen their industrial competitiveness by providing support for technological development and securing of raw materials. The Government should assist solar cell manufacturers and other solar power generation industries so that they will be able to play a central role in the future industrial structure of Japan.

The main policy drivers in Japan can be summarised by the following bullet points given by METI:

- Contribution to securing a stable energy supply as an oil alternative energy;
- Clean energy with a small burden on the environment;
- Contribution to new industry and job creation;
- Advantage of creating a decentralised energy system;
- Contribution of load levelling for electric power (effect reducing energy peaks).

The latest development is the enactment of the new law on the Promotion of the Use of Nonfossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers on 1 July 2009. With this law, the purchase of “excess” electricity from PV systems is no longer based on a voluntary agreement by the electric utility companies but it becomes a National Programme with cost burden sharing of all electricity customers.

- The outline of the new programme to purchase surplus electricity from PV systems is the following:
  - Obligation of utility companies to purchase PV power at a fixed price.
  - Eligible for the fixed price are PV systems on residential and non-residential buildings which are grid connected and have contracts with an electricity utility company (reverse flow). PV systems designed for power generation and systems larger then 500 kWp are not eligible.
  - The fixed price in FY 2009 are:
    - 48 ¥/kWh (0.37 €/kWh) for PV systems < 10 kW on residential houses
    - 39 ¥/kWh (0.30 €/kWh) for residential houses with double power generation, e.g. PV + fuel cells, etc.
    - 24 ¥/kWh (0.18 €/kWh) for PV systems on no-residential houses.
  - The rates are fixed for 10 years.
  - The purchase price will be reviewed and decreased by the Subcommittee on Surplus Power Purchase Programme annually.
  - All electricity users will equally bear the costs of the PV surcharge.
3.2 Implementation of Photovoltaics

The Japanese residential implementation programme for Photovoltaics, which ended in October 2005, was the longest running. It started with the “Monitoring Programme for Residential PV systems” from 1994 to 1996, followed by the “Programme for the Development of the Infrastructure for the Introduction of Residential PV Systems”, which has been running since 1997. During this period, the average price for 1 kWp in the residential sector fell from 2 million ¥/kWp in 1994 to 670,000 ¥/kWp in 2004. With the end of the “Residential PV System Dissemination Programme” in October 2005, the price data base of the New Energy Foundation (NEF) was no longer continued.

The Residential PV System Dissemination Programme has been leading the expansion of Japan’s PV market for 12 years. In 2006, 88.5%, or 254 MW of the new installations were grid-connected residential systems, bringing the accumulated power of solar systems under the Japanese PV Residential Programme to 1,617 MW, out of 1,709 MW total installed PV capacity at the end of FY 2006 [Mat 2007]. However, in FY 2007 the Japanese market declined to 210 MW and only recovered slightly to 230 MW in 2008 [Ohi 2009, Epi 2009]. At the end of 2008, total cumulative installed capacity was 2.15 GW, less than half of the original 4.8 GW goal for 2010.

In general, the end of the Residential PV System Dissemination Programme in FY 2005 was considered the main reason for the decrease of new installations, but not so much because of the financial incentive of ¥ 20,000 per kWp, but because this was perceived as lack of political support. In order to stop the downward trend of the Japanese market and to stimulate the home market, METI announced at the end of August 2008 that they wanted to reinstate an investment subsidy for residential Photovoltaic systems in FY 2009 and that they have submitted a budget request. These new measures to revitalise the Japanese market, as well as METI’s “Vision for New Energy Business” (June 2004), the “New National Energy Strategy” (June 2006) and the “Action Plan for Promoting the Introduction of Solar Power Generation” (November 2008) confirm the political support for renewable energies.

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These activities are aimed to develop an independent and sustainable new energy business and various support measures for PV are explicitly mentioned. The key elements are:

1) Strategic promotion of technological developments as a driving force for competitiveness:
   - Promotion of technological development to overcome high costs;
   - Development of PV systems to facilitate grid-connection and creation of the environment for its implementation.

2) Accelerated demand creation:
   - Develop a range of support measures besides subsidies;
   - Support to create new business models.

3) Enhancement of competitiveness to establish a sustainable PV industry:
   - Establishment of standards, codes and an accreditation system to contribute to the availability of human resources, as well as securing performance, quality and safety;
   - Enhancement of the awareness for Photovoltaic systems;
   - Promotion of international co-operation.

The number of Japanese Ministries working on support measures to install PV systems has expanded from METI to the Ministry of the Environment (MOE), the Ministry of Land, Infrastructure and Transport (MLIT) and the Ministry of Agriculture, Forestry and Fisheries of Japan (MAFF).

The Federation of Electric Power Companies of Japan (FEPC) announced that they intend to install PV plants with a cumulative installed capacity of 10 GW by 2020 [Ikk 2008].
Table 2: Key points of PV2030+ scenario for future growth of PV power generation

<table>
<thead>
<tr>
<th>Target (completion of development)</th>
<th>2010 or later</th>
<th>2020 (2017)</th>
<th>2030 (2025)</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power generation cost</td>
<td>Equivalent to household retail price (23 ¥/kWh)</td>
<td>Equivalent to commercial retail price (14 ¥/kWh)</td>
<td>Equivalent to general power generation (7 ¥/kWh)</td>
<td>Equivalent to general power generation (7 ¥/kWh or below)</td>
</tr>
<tr>
<td>Commercial module conversation (Lab. efficiency)</td>
<td>16% (20%)</td>
<td>20% (25%)</td>
<td>25% (30%)</td>
<td>ultra high performance modules with 40% added</td>
</tr>
<tr>
<td>Production for Japanese Market [GW/annum]</td>
<td>0.5 - 1</td>
<td>2 to 3</td>
<td>6 to 12</td>
<td>25 - 35</td>
</tr>
<tr>
<td>Production for Export [GW/annum]</td>
<td>ca 1</td>
<td>ca 3</td>
<td>30 - 35</td>
<td>ca 300</td>
</tr>
<tr>
<td>Major applications</td>
<td>single family houses, public facilities</td>
<td>single/multi family houses, public facilities, commercial buildings</td>
<td>single/multi family houses, public facilities, consumer use, charging Evs, etc.</td>
<td>consumer use, industries, transport, agriculture, etc., stand alone power source</td>
</tr>
</tbody>
</table>
In 2004, NEDO, METI, PVTEC and JPEA drafted the “PV Roadmap towards 2030” (Fig.7) [Kur 2004]. The world-wide changes of circumstances, especially the rapid growing Photovoltaic production and markets, as well as the accelerated growth of energy demand in Asia, together with a changed attribute towards Climate Change and the necessary greenhouse gas reductions in Japan, have led to a revision of the Roadmap PV2030 to 2030+. The review aims at further expanding PV usage and maintaining the international competitiveness of Japan’s PV industry.

The 2030 Roadmap has been reviewed and the goal has been changed from “making PV power generation one of the key technologies by 2030” to “making PV power generation one of the key technologies, which plays a significant role in reducing CO₂ emissions by 2050, so that it can contribute not only to Japan, but also to the global society”.

In PV2030+, the target year has been extended from 2030 to 2050 and a goal to cover between 5 and 10% of domestic primary energy demand with PV power generation in 2050 was set. PV2030+ assumes that Japan can supply approximately one-third of the required overseas market volumes (Table 2). To improve economic efficiency, the concept of “realising Grid Parity” remained unchanged and the generation cost targets remained unchanged from PV2030. In addition, PV2030+ aims to achieve generation cost of below 7 ¥/kWh in 2050. Regarding the technological development, an acceleration to realise these goals is aimed to achieve the 2030 target already in 2025, five years ahead of the schedule set in PV2030. For 2050, ultra-high efficiency solar cells with 40% and even higher conversion efficiency will be developed.

3.3 NEDO PV Programme

In Japan, the Independent Governmental Entity New Energy Development Organisation (NEDO) is responsible for the Research Programme for Renewable Energies. The current programme for Photovoltaics in the frame of Energy and Environment Technologies Development Projects has three main pillars [NED 2007]:

- New Energy Technology Development
- Introduction and Dissemination of New Energy and Energy Conservation
- International Projects

One of the dominant priorities, besides the future increase in PV production, is obviously the cost reduction of solar cells and PV systems. In addition to these activities, there are programmes on future technology (in and outside NEDO) where participation of Japanese institutes or companies occurs by invitation only. For the participation of non-Japanese partners, there are “future development projects” and the NEDO Joint Research Programme, mainly dealing with non-applied research topics.

Within the New Energy Technology Development Programme there are projects on Photovoltaic technology specific issues, problems of grid-connected systems, as well as public solicitation.

Field Test Projects on Photovoltaic Power Generation FY2007 - FY2014 (Installation work to be completed in FY2010)

To further promote the introduction of PV systems, it is considered essential to install them at public facilities, residential housing complexes, and in the industrial sector, such as at factories. The potential of such installations is comparable to that of the detached home market. Medium- and large-scale PV systems are being adopted more slowly than detached home systems, even though costs have been substantially reduced and their effectiveness as power generation devices has been verified. Systems employing new modules or other innovations will be verified through joint research activities (partly covered by technology research subsidies). Operating data is being analysed, evaluated, and published with the objective of encouraging further cost reductions and system performance improvements. NEDO and joint researchers each bear 50% of the costs.

Development of Technologies to Accelerate the Practical Application of Photovoltaic Power Generation Systems FY2008 - FY2009

Technical development is needed to significantly increase the efficiency of photovoltaic (PV) power generation systems and to achieve a generation cost target of 14 yen/kW by 2020. Through various projects, including Research and Development of Next-generation PV Generation System Technologies, NEDO is supporting research and development of elemental technologies, which are considered to be mid- or long-term challenges in order to determine the feasibility of the technologies. While many foreign companies are actively participating in the PV market, NEDO’s aim is to maintain Japan’s competitiveness in PV technology development and strengthen its industrial structure. To achieve these goals,
NEDO supports efforts in certain technology fields that have the potential for an early practical application, including full-scale production, commercialisation and market competitiveness by 2015.

With these general goals, the objectives of this project are the early practical application of elemental technologies for advanced solar cell fabrication, leveraging past technical research and development, and the development of PV generation technology capable of providing a substantial part of Japan’s future long-term energy supply. To maintain the competitiveness of Japan’s technology development, NEDO provides subsidies (a subsidy ratio of 50%) for projects that address the following challenges:

- Enhanced production technologies for thin-film silicon solar cells (including super large area cell production and high-speed film production) and light-weighting technology
- Slicing techniques for ultra thin polycrystalline silicon solar cells
- Selenisation process optimisation techniques for CIS thin-film solar cells

### Research and Development of Next-generation PV System Technologies
FY2006 - FY2009

To play an important role in energy generation in the future, the cost-effectiveness, performance, function, applicability, and usability of Photovoltaic systems must be drastically improved to facilitate the promotion and dissemination of solar power generation. Given this, medium- to long-term innovative technological development efforts beyond simple extensions of currently available technologies are underway. More specifically, the following research and development themes are being undertaken:

- **Technologies to enable higher productivity and to improve the efficiency of thin-film silicon solar cells.**
  *High Productivity Targets:*
  1. $\mu\text{c-Si}$ thin-films with large area (4 m²)
     - deposition rate > 2.5 nm/s and single junction cell efficiency > 8%
  2. $\mu\text{c-Si}$ thin-films 100 cm² substrates
     - deposition rate > 10 nm/s and single junction cell efficiency > 8%
  3. Thin-film silicon etching rate: 20 nm/s
  *High Efficiency:*
     - 15% for module area of 1000 cm² with (film deposition rate: 2.5 nm/s)

- **Technologies to enable highly efficient, modular, and durable dye-sensitised solar cells.**
  High efficiency of 15% for small area (1 cm²) cells
  Durability of modules with target efficiency of 8% (900 cm²)

- **Technologies and associated processes to produce highly efficient next-generation ultra-thin crystalline silicon solar cells.**
  Development of production technology for crystalline silicon solar cells with a
  - Monocrystalline: 100-µm substrate thickness, 125 x 125 mm² and 21% efficiency
  - Polycrystalline: 100-µm substrate thickness, 150 x 150 mm² and 18% efficiency

- **Technologies to improve the efficiency and durability of organic thin-film solar cells.**
  Target efficiency of 7% for small area (1 cm²) cells
  Relative efficiency degradation ≤ 10% after 100 hours of exposure to air and direct light

- **Search for next-generation technologies that would enable significant cost reductions, improved performance, and extend the usable life of solar power generation systems.**

### Research and Development on Innovative Solar Cells
FY2008 - FY2014 (peer review after 3rd year)

The objective of this project is to improve drastically the conversion efficiency of solar cells using new and innovative concepts. Tokyo University and AIST Tsukuba in collaboration with the Tokyo Institute of Technology were selected in July 2008 as Centres of excellence (CoE) to carry out the tasks. The following research topics were selected and are open for international collaboration:
- **Post-silicon Solar Cells for Ultra-high Efficiencies**
  1. Super high-efficiency concentrator multi-junction solar cells
  2. High efficiency quantum structure tandem solar cells and their manufacturing technologies
  3. Ultra-high efficiency solar cells based on quantum dots and super lattice
  4. Ultra-high efficiency multiple junction solar cells with hybrid materials

- **Thin-film Full Spectrum Solar Cells with low concentration ratios**
  1. Band-gap control of nano dots/ multi-exiton/ band-gap engineering of strained Ge/ novel Si-based and amorphous alloy thin-films/ thin-film materials design
  2. Si-based thin-film concentrators/ wide band-gap Si based thin-films/ multi-cell interface junction/ Chalcopyrite based thin-film concentrators on metal substrates/ optical design/ CdTe thin-film concentrators
  3. Surface plasmons/ p-type TCO/ full-spectrum TCO/ graphene transparent conductive film

- **Exploring Novel Thin-film Multi-junction Solar Cells with Highly-ordered Structure**
  1. Highly-ordered plane poly-silane/ ordered nano-crystalline Si-materials/ Ge-based narrow band-gap materials/ heterojunction devices
  2. Wide band-gap chalcogenide-based materials/ solar cells using novel wide band-gap material/ Oxynitride-based wide band-gap materials/ Oxide-based wide band-gap materials/ CIGSSe-based tandem-type solar cells
  3. Novel concept solar cells using nano-Si, nano-carbon and single-crystalline organic semiconductors/ novel concept solar cells using correlated materials/ novel concept solar cells using nano-materials with controlled structure
  4. Mechanical stacking-techniques/ highly efficient light-trapping techniques/ improved transparent conduction oxide films using preparation techniques for improved glass substrates

- **Development of new solar cell evaluation technologies**
  To increase the number of installations, methods to evaluate the performance and reliability of solar cell modules and solar generation systems are being developed.

- **Development of Photovoltaic environmental technologies**
  Studies are being conducted under a variety of environmental conditions and guidelines for Photovoltaic (PV) generation systems. The development of technologies related to solar cell recycling and the development of life-cycle assessment (LCA) evaluation methods for PV generation are also being carried out.

- **Study on Photovoltaic generation technology development trends**
  Research and development trends, future development directions, and the analysis and evaluation of the state of PV generation abroad are being tracked.

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**Research and Development of Common Fundamental Technologies for Photovoltaic Generation Systems**
FY2006 - FY2009

To facilitate the dissemination of Photovoltaic generation systems in the future, it is essential to develop and incorporate commonly-used fundamental technologies and to reduce the cost of solar cells. For this purpose, the following research and development activities are currently ongoing:

**Research and Development of Islanding Detection Testing Technology for Clustered Photovoltaic Power Generation Systems**
FY2008 - FY2009

The Demonstration Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems, conducted between FY2002 and FY2007, a new technology for an islanding detection system was developed, targeting any residential photovoltaic power generation system (PV system) within a cluster. However, the current certification scheme in Japan for grid connection protection devices for PV systems is only applicable to single PV systems, and therefore does not ensure the proper operation of protection devices for clustered PV systems connected to a common grid. To further disseminate PV systems, it is necessary to develop protection technology that can be applied to clustered PV systems connected to a grid and to establish testing technology to verify the protection. Using the experimental equipment and achievements of the Demonstration Project on Grid-interconnection of Clustered Photovoltaic Power Generation Systems, the aim of this research and development project is to establish testing technology that will also contribute to the certification of islanding detection systems for clustered grid-connected PV systems.
Verification of Grid Stabilisation with Large-scale PV Power Generation Systems
FY2006 - FY2010

It is expected that large-scale Photovoltaic (PV) generation systems will be increasingly disseminated. When a number of such large-scale PV systems are connected to power grids, there is a concern that the fluctuating output inherent to PV systems could affect the voltage and frequency of power on utility power grids, and result in restrictions that limit the dissemination and practical application of PV systems. To investigate this problem, the following work will be carried out:

- Development and verification of the effectiveness of various technologies required when large-scale PV systems are connected to power grids, including voltage fluctuation suppression technology, frequency (output) fluctuation suppression technology, large-scale PV output control technology to enable scheduled operations, and harmonic suppression technology. Large PV power conditioners capable of stabilising grids will also be developed.

- Development of simulation methods to apply to the above research topics, which will also be useful for studying specific conditions in preparation for future large-scale PV system installations.

Project to Support Innovative New Energy Technology Ventures
FY2006 - FY2011

The purpose of this project is to promote the technological development of fields related to untapped energies, including new sources/technologies such as (1) Photovoltaic power generation, (2) Biomass, (3) fuel cells and batteries, (4) wind power generation and unutilised energy sources. More specifically, the project aims to make full use of the promising technological seeds that are held by venture companies and other organisations, to identify new technologies that can boost efforts to introduce and popularise new energy systems by 2010 and beyond through creating and expanding new businesses, and to launch new venture companies.

The Introduction and Dissemination of New Energy and Energy Conservation Programme consists of various promotional and awareness campaign projects.

Project for Promoting the Local Introduction of New Energy
FY1998 - open

This project is designed to accelerate the introduction of the New Energy Facility Introduction Project and the New Energy Introduction Promotion/Dissemination Project, which are implemented by local Governments. The facility introduction project subsidizes local Governments for up to 50% of equipment/facility introduction costs and up to 20 million yen for dissemination.

Non-profit organisations are also eligible for support under the New Energy Facility Introduction Project if they introduce effective new energy utilisation systems at local level. To disseminate the efforts of non-profit organisations nationally in order to accelerate the dissemination of new energy, projects can be subsidised at up to 50% of the cost.

The International Projects mainly focus on neighbouring Asian developing countries to promote technological development.

International Co-operative Demonstration Project Utilising Photovoltaic Power Generation Systems
FY1992 – open

The technological development necessary for the practical application and dissemination of Photovoltaic power generation systems cannot be achieved without the efficient promotion of system improvements, including system reliability verification and demonstration, as well as cost reductions. NEDO conducts the International Co-operative Demonstration Project Utilising Photovoltaic Power Generation Systems with developing countries whose natural conditions and distinctive social systems are rarely seen in Japan.

Demonstrative Research Project on Integrated Control Technology for Large-scale Photovoltaic Systems
(High-capacity PV + Capacitor + Integrated control)
Country of Implementation: China (Qinghai)
FY2006 - FY2009

Substantial efforts are being made to increase the capacity of Photovoltaic power generation systems. There is, however, a concern that the short-term output fluctuations of Photovoltaic power generation systems can cause voltage variations and degrade electric power quality. In this project, the stabilisation of power supplies through the use of electric double-layered capacitors will be verified. Besides being able to compensate for...
output variations in general, electric double-layered capacitors rapidly respond to instantaneous voltage variations, are easily serviceable, and have less environmental impact when disposed of. Other points to be verified in this project include failure response technology to be applied during power system failures or other incidents, as well as other space- and equipment-saving measures required when system capacity increases significantly. The site for this demonstrative project is the Xining National Economic and Technological Development Area in Xining City, Qinghai Province, China.


By utilising the data and knowledge obtained through NEDO's international co-operative demonstration projects, including those related to Photovoltaic power generation systems, highly reliable design support tools will be developed reflecting the field results in order to improve the accuracy and accelerate design efforts regarding the capacity, output, and economic efficiency of Photovoltaic power generation systems.


In order to further raise the technological knowledge level and to popularise the use of reusable energies through the use of technologies such as Photovoltaic generation systems, it is necessary to obtain sufficient knowledge of the methods and techniques to enable the efficient use, maintenance and management of the systems. Presently, however, education and training systems to systematically provide information on reusable energies are not widely available in most Asian countries. To address this situation, NEDO, using results and knowledge obtained through international co-operative demonstration projects, will help other Asian countries implement education and training for selected engineering managers. These individuals will then become master trainers in their home countries. NEDO will prepare textbooks and training curriculum for the participating countries, and implement education and training courses to be delivered by the master trainers to trainers and students in their own countries. The School of Renewable Energy Technology (SERT) at Naresuan University in Thailand serves as the centre for this project. SERT was chosen in part because of its efforts to develop renewable energy education programmes, including a curriculum on Photovoltaic power generation systems.


In order to prepare for the future large-scale introduction of renewable energy solutions like photovoltaic (PV) power generation systems, technologies that enable a stable supply of electric power with minimum voltage and frequency variations, even when operated independently from power grids, are required for renewable energy microgrids built near energy demand sites. In this project, experimental development will be carried out to address such technical challenges in order to allow these microgrids to produce a stable supply of electric power.

3. 4 Japanese Market Situation

Japanese Photovoltaic production has rapidly increased following the development of roof-type technologies and the introduction of the subsidy system “Programme for the Development of Infrastructure for the Introduction of Residential PV Systems” in 1997. After the end of the Residential Market Implementation Programme which was widely received as a slowing political support, the Japanese market has decreased from about 290 MW in 2005 to 210 MW in 2007 and recovered slightly with 230 MW in 2008. The total cumulative installed capacity in 2008 was 2.15 GW, less then half of the original 4.8 GW goal for 2010 [Ohi 2009, Epi 2009].

After 30 years of PV development under the different NEDO programmes, 11 Japanese PV manufacturing companies have produced solar cells in 2008 [Ikk 2009] and approx. 17% (1220 MWp) of the solar cells world-wide. Despite an overall Japanese production growth of more than 30% from 2007 to 2008, Japanese manufacturers lost overall market shares due to the doubling of world-wide production.

All Japanese solar cell manufacturers have announced massive increases of production capacities for 2010 onwards, signalling the expectations for a continuation of the high growth rates of the world market. If the announced capacity increases are realised, production capacity in Japan would increase from 1.5 GW in 2007 to 4.5 GW in 2010 and close to 7 GW in 2012.

A new investment subsidy system was introduced by METI and started in January 2009 under a supplementary budget for FY 2008 and a volume of ¥ 9 billion (€ 69 million). For FY 2009 the programme has a budget volume of
¥ 20.05 billion (€ 154 million). The new subsidy is 70,000 ¥/kWp (€ 540) and will be available for systems smaller than 10 kWp, and only if the system costs are below 700,000 ¥/kWp. The allocated budget for the last months of FY2008 (January – March 2009) and FY2009 would allow the installation of more than 100,000 systems, or 400 MW.

METI started to review the Renewable Portfolio Standard (RPS) Law in order to prepare the introduction of a new PV power purchase programme. The new law was enacted on 1 July 2009 and sets a fixed price for the purchase of “excess” electricity from eligible PV systems at a higher rate then the current residential electricity price of 24¥/kWh (details see Chapter 3.1). It is planned to start with this programme at the end of FY2009 and the purchase price of 48¥/kWh for residential systems smaller than 10 kWp should allow a pay-back period of approximately 10 years. The draft of the new RPS law sets a target of 3.89 TWh for electricity generated by PV systems under the new power purchase programme in 2014.

In addition to the National Government, Local Government and Utilities have announced plans as well. The Tokyo Metropolitan Government implemented a plan to install 1 GW within the next 10 years and supports the installation of residential PV systems with an additional 100,000 ¥/kWp in FY 2009 and FY2010. Other prefectures and cities have also announced implementation plans and are offering additional investment incentives as well.

So far, the majority of PV systems were installed on residential houses. At the end of FY 2008, about 1.75 GWp, out of the total 2.15 GWp installed, were on residential buildings. It is interesting to note that the number of real roof integrated houses is rather small, despite the fact that such solutions are readily available. One of the reasons for this is that people investing in PV systems want to “exhibit” them in order to show their environmental consciousness and lifestyle.

In June 2006 the Japanese Photovoltaic Energy Association published its vision on the “Future of the Photovoltaics Industry in Japan” in response to METI’s “New National Energy Strategy” in June 2006 [Ikk 2006]. This vision paper was a revision of the 2002 version, taking into account the significant increase of the world PV market, as well as soaring crude oil and energy prices. The figures given in this vision for the expected domestic market of 1.18 GW for 2010 were still in view of the cumulative installed capacity target of 4.8 GW for 2010 and 100 GW in 2030.

This 2030 Roadmap has been reviewed and the new PV2030+ version has extended the time horizon from 2030 to 2050. The new motto is “making PV power generation one of the key technologies, which plays a significant role in reducing CO2 emissions by 2050, so that it can contribute not only to Japan but also to the global society”.

In PV2030+, the Japanese domestic market for 2010 is estimated between 0.5 and 1 GW and the predictions for 2020 and 2030 are equally moderate with 2 to 3 GW in 2020 and 6 to 12 GW in 2030. PV2030+ assumes that Japan can supply approximately one-third of the required overseas market volumes (Table 2).

In an interview with Photon International during the PV Japan 2008 Fair in Tokyo (30 July – 1 August 2008), Junichi Honda,
Manager of the Japan Photovoltaic Energy Association (JPEA), expressed his view that in his opinion the domestic market should be in the range of 35 to 40% of the Japanese actual production. This would be close to JPEA’s 2006 vision figures and it has to be seen if the market stimulus by a new residential PV programme is sufficient to realise it. But even if the new programme is approved, the capacity of all installed PV systems in Japan will be in the range of 3 GW in 2010 (Fig. 8). This is in line with the PV2030+ assumption that Japan could provide about 35% of the production required by overseas markets.

A special condition of the Japanese PV industry is the fact that most of the production capacities are limited to a few large companies, which bundle the whole, or at least large portions, of the PV value chain inside their own company, i.e. the solar cell, module, BOS components and sometimes even the installation and maintenance of the PV systems, are offered from the same company. This development is fostered by the special situation of the Japanese construction market. The average lifetime of a residential home is 25 to 35 years and corresponds well with the lifetime of solar modules. A lot of houses are either prefabricated or construction companies use standardised building components, favourable for the integration of solar modules. This advantage was recognised by the solar cell manufacturers and they have either bought housing or construction companies, or forged strategic alliances with such companies.

3.5 Solar Companies

In the following chapter, most of the market players in Japan are briefly described. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was very fragmentary.

3.5.1 Kaneka Solartech

Kaneka has been involved in the development of amorphous solar cells for over 25 years. Initially this was aimed at the consumer electronics market, but overall R&D, as well as business strategy, was changed in 1993 when Kaneka decided to move into the power module market for residential and industrial applications.

Currently Kaneka produces a-Si and amorphous/microcrystalline silicon modules for rooftop application and built-in roofing types for the Japanese, as well as export markets. The built-in roofing types were developed for the Japanese housing market in co-operation with Quarter-House and Kubota and are either shingle type modules or larger roofing elements. In 2006 the company opened a module factory in Olomouc, Czech Republic, where the capacity was increased to 30 MW in 2008. In FY2008 the total production capacity was expanded to 70 MWp/year. A further expansion to 150 MW in 2010 and to 1 GW in 2015 was announced early 2009 [Kan 2009]. In FY 2008 production was 52 MW [Pvn 2009].

3.5.2 Kyocera Corporation

In 1975 Kyocera began with research on solar cells. The Shiga Yohkaichi Factory was established in 1980 and R&D and manufacturing of solar cells and products started with mass production of multicrystalline silicon solar cells in 1982. In 1993 Kyocera achieved a 19.5 % world record efficiency with single-crystal silicon solar cells (10 cm²). In the same year Kyocera started as the first Japanese company to sell home PV generation systems.

In 2008, Kyocera had a production of 290 MW and is also marketing systems that both generate electricity through solar cells and exploit heat from the sun for other purposes, such as heating water. The Sakura Factory, Chiba Prefecture, is involved in everything from R&D and system planning to construction and servicing and the Shiga factory, Shiga Prefecture, is active in R&D, as well as the manufacturing of solar cells, modules, equipment parts, and devices, which exploit heat. Like other Japanese manufacturers, Kyocera is planning to increase its current capacity of 300 MW to 500 MW in 2010 and 650 MW by 2012 [Kyo 2008].

The growing markets in developing countries are of major interest to the company. Therefore, Kyocera set up a joint venture with the Tianjin Yiqing Group (10% share) in Tianjin, China, to produce PV modules for the local market. The factory started operation in October 2003 and the current production of 60 MW is expanded to 240 MW in 2012 [Kyo 2009]. A second module factory with 36 MW production capacity in Tijuana, Mexico, started production in December 2004 and the expansion to 150 MW should be finished in 2010 [Kyo 2009a]. In order to supply the growing European market, Kyocera set up a third module assembly plant in Kadan, Czech Republic, which started operation in 2005, with a production capacity of 60 MW annually. The capacity of this plant is scheduled to be increased to 150 MW by early 2011 [Kyo 2007].

3.5.3 Mitsubishi Electric

In 1974 research and development of Photovoltaic modules was initiated. In 1976 Mitsubishi Electric established its space satellite business and 1986 saw the beginning of a public and industrial systems business. One of the largest PV systems in Japan was delivered in 1993 to Miyako Island in the Okinawa Prefecture (750 kWp). With the start of the NEDO Residential Programme, Mitsubishi Electric got involved
in the residential PV market in 1996. The Iida factory, Nagano Prefecture, was established in 1998 where cells and modules were manufactured. Today this plant is used for cell production and the modules are manufactured in Nakatsugawa, Gifu Prefecture, and Nagaokakyo, Kyoto Prefecture. Current production capacity is 220 MW [Mit 2008] and production in 2008 was 148 MW [Pvn 2009].

3.5.4 Mitsubishi Heavy Industries
Mitsubishi Heavy Industries (MHI) started their pilot plant production in 2001, because solar energy has attracted increasing attention as an environment-friendly form of energy. In 2008 MHI produced 40 MW of amorphous silicon solar cells and it is planned to increase the current production capacity of 128 MW to 600 MW in 2010.

The plasma CVD deposition used by MHI allows rapid deposition on large size glass and flexible substrates (roll-to-roll). MHI has stabilised the a-Si single-junction efficiency at 8%, starting with 10% initial efficiency. The degradation process lasts for approximately 3 to 4 months, before the stabilised efficiency is reached. Long-time outdoor exposure tests performed at JQA showed that the stabilised efficiency does not change and that the lifetime expectancy can be rated at 20 to 25 years. Mitsubishi is currently working on improving the efficiency to 12% by using a microcrystalline/a-Si structure in the future. Another feature of the Mitsubishi modules is their high voltage. The modules are produced with either 50V or 100V and power ratings between 24 and 100Wp.

3.5.5 SANYO Electric Company
Sanyo commenced R&D for a-Si solar cells in 1975. 1980 marked the beginning of Sanyo’s a-Si solar cell mass productions for consumer applications. Ten years later in 1990 research on the HIT (Heterojunction with Intrinsic Thin Layer) structure was started. In 1992 Dr. Kuwano (former president of SANYO) installed the first residential PV system at his private home. Amorphous Silicon modules for power use became available from SANYO in 1993 and in 1997 the mass production of HIT solar cells started. In 2008 Sanyo produced 210 MW solar cells [Pvn 2009]. The company announced to increase its current production capacity of 340 MW HIT cells to 600 MW by 2010 [San 2009].

At the end of 2002, Sanyo announced the start of module production outside Japan. The company now has a HIT PV module production (50 MW/a) at SANYO Energy S.A. de C.V.’s Monterrey, Mexico and it joined Sharp and Kyocera to set up module manufacturing plants in Europe. In 2005 it opened its module manufacturing plant in Dorog, Hungary, and the production capacity was increased to 145 MW in 2008.

Sanyo has set a world record for the efficiency of the HIT solar cell with 23% under laboratory conditions [San 2009a]. The HIT structure offers the possibility to produce double-sided solar cells, which offer the advantage to collect scattered light on the rear side of the solar cell and can therefore increase the performance by up to 30% compared to one-sided HIT modules in the case of vertical installation.

Fig. 9: Sanyo’s Solar Ark
(Picture: courtesy of Sanyo)
Sanyo works closely with Daiwa House to promote the HIT power roofing tile. The advantages are the lower weight (50%) compared to a conventional roof tile. Like other big Japanese solar companies Sanyo offers the complete PV systems manufactured by its own factories.

Solar Ark Project: The “Solar Ark”, a large scale solar power generation system (630 kWp) at SANYO’s Gifu facility was completed in December 2001 and is a symbol of solar energy well known in the whole of Japan. The Solar Ark was built in the image of an Ark embarking into the 21st century, powered by solar energy (Fig. 9).

The Ark’s total length measures 315 metres, with its highest point measuring 37.1 metres, making it the largest single-structure solar installation in the world. In the meantime, it has become one of the symbols of Photovoltaics. Placed underneath the Ark is the “Solar Lab”, a Solar Energy Museum opened in 2002. The main activities are:

- Cultivating children’s awareness in Science and Ecology.
- Releasing information from the standpoint of benefiting mankind and the environment.
- Regional contribution, such as support for the development of Eco-Town.
- Creation of new ideas through various activities.

3.5.6 Sharp Corporation

Sharp started to develop solar cells in 1959 and succeeded in mass-producing them in 1963. Since its products were mounted on “Ume”, Japan’s first commercial-use artificial satellite, in 1974, Sharp has been the only Japanese maker to produce silicon solar cells for use in space. Another milestone was achieved in 1980, with the release of electronic calculators equipped with single-crystal solar cells. Sharps aims to become a “Zero Global Warming Impact Company by 2010” as the World’s Top Manufacturer of Solar Cells.

In 2008 Sharp had a production capacity of 855 MWp/year [Sha 2007a] and produced 473 MW [Pvn 2009]. An enhanced production line (15 MW), for new large format thin-film polycrystalline solar cells, went into operation in September 2005 and was expanded to 160 MW in FY2008. The newly developed “Thin-Film Crystalline Tandem Cell” consists of an upper amorphous silicon solar cell and a lower crystalline thin-film silicon solar cell [Sha 2004]. The thin-films can either be manufactured as see-through (illuminating PV module “Lumiwall”, integrating light emitting diodes) or non see-through modules. After the announcement that their triple-junction thin-film solar cell, with an increased module efficiency of 10%, would go into mass production in May 2007 [Sha 2007b], the company announced the construction of a 1 GW thin-film plant by 2010 [Sha 2007]. During the 1st International Photovoltaic Power Generation Expo in Tokyo on 27 February 2008, Sharp announced to increase thin-film production capacity beyond the original foreseen 1 GW to 6 GW after 2012.

Together with Daido Steel and Daido Metal, Sharp developed a super high-efficiency Compound Solar Cell used for low cost solar concentrator modules and tracking systems within a NEDO research project. The InGaP/InGaAs/Ge solar cell has an efficiency of 36% under 700 X concentration. The tracking system has a size of 3.8 x 4.8 m² and the system output is 2,922 W. According to a press release from September 2007, the system is now available [Sha 2007c].

The company has close collaboration with major Japanese housing companies and offers complete PV systems with all components made within the company.

In addition to the solar cell factory at the Katsuragi Plant, Nara Prefecture, Sharp has five module factories and has established the Toyama factory to produce silicon. Three of the module factories are outside Japan, one in Memphis, Tennessee, USA with 70 MW capacity, one in Wrexham, UK, with 220 MW capacity and one in Nakornpathom, Thailand. In November 2008, the company announced to establish a joint venture with the Italian Enel SpA to build and operate a number of photovoltaic power plants with a total capacity of 189 MW by the end of 2012 [Sha 2008]. The companies also signed an MoU to set up a manufacturing plant with an initial capacity of 480 MW in 2010.

3.5.7 Showa Shell Sekiyu:

In 1986 Showa started to import small modules for traffic signals, and started module production in Japan, co-operatively with Siemens (now Solar World). The company developed CIS solar cells and completed the construction of the first factory with 20 MW capacity in October 2006. Commercial production started in FY 2007. In August 2007 the company announced the construction of a second factory with a production capacity of 60 MW to be fully operational in 2009 [Sho 2007]. In July 2008 the company announced to open a research centre “to strengthen research on CIS solar powered cell technology, and to start a collaborative research on mass production technology of the solar modules with Ulvac, Inc.” [Sho 2008]. The aim of this project is to start a new plant in 2011 with a capacity of 1 GW.
3.5.8 Additional Solar Cell Companies

- **Clean Venture 21**: Clean Venture 21 Corporation was founded in 2001 as a privately held solar company and develops spherical Silicon solar cells. In 2006 CV21 opened its first production facility in Kyoto. The company claims that the cells have 12% efficiency and that the costs should be only one fifth of a conventional silicon cell due to the significantly reduced silicon use. CV21 entered into an exclusive sale agreement with FujiPream Corporation in December 2005. According to RTS Corporation, the company has a production capacity of 12 MW for spherical silicon solar cells [Ikk 2009].

- **Fuji Electric Systems Co. Ltd.**: In 1993 Fuji Electric started its activities in amorphous thin-film technology. The company developed amorphous-silicon thin-film solar cells in the framework of a NEDO contract. The cells, which use a plastic film substrate less than 0.1mm thick, are light, inexpensive to manufacture and easily processed into large surface areas. In 2005 Fuji announced the construction of a factory with an initial capacity of 12 MW to be expanded to 40 MW in 2009 [Fuj 2007].

- **Hitachi**: Tokyo-based Hitachi Ltd. had a production capacity for its bi-facial crystalline solar cell of 10 MW/a, but sold it to Space Energy Corporation in April 2008. In addition, Hitachi developed a dye-sensitised solar cell with 9.3% efficiency according to the company.

- **Honda Soltec Co. Ltd.**: Honda R&D Co. Ltd. developed a CIGS thin-film module with a power output of 112W. To commercialise the product, Honda Soltec Co. Ltd was established on 1 December 2006. Since June 2007, the company is selling 125 W modules produced by Honda Engineering Co. Ltd. and announced that the mass production at the Kumamoto Plant, with an annual capacity of 27.5 MW, started its production in November 2007 [Hon 2007].

- **Kyosemi Corporation** was founded in 1980 and is a research and development-oriented optoelectronic company. The company developed a proprietary spherical solar cell and in 2004 registered the trademark Sphelar®.

- **Matsushita Ecology Systems**: National/Panasonic produces a colourable Photovoltaic cell (PV) and module especially for commercial use. Applications are building roofs, wall mountings and glass windows. They design and select the most suitable products, and supply individual solar modules or cells. In addition, Matsushita is involved in research of CIGS thin-film modules.

- **Sanyo – Eneos Solar Company** was established in January 2009 by SANYO Electric Co., Ltd. and Nippon Oil Corporation with the aim of producing and commercialising reliable thin-film PV modules. The new joint company will start production and sales at an initial scale of 80 MW in Fiscal Year 2010 and gradually increase its production capacity while reviewing and considering the market needs. The goals for the future scope of business are 1GW for annual global production and sales by FY2015 and around 2GW for the annual global production and sales of thin-film solar by FY2020.

- **Space Energy Corporation**: The company was established in April 1995 under the name Metal Reclain Corporation and produces wafers. In April 2008 the company bought Hitachi’s bi-facial solar cell and module manufacturing facility and started to set up a factory in Nagano with an initial capacity of 3.5 MW to be expanded to 8 MW in 2009.

3.5.9 Kobelco (Kobe Steel)

In April 1999, Kobe Steel's Engineering Company formed an agreement with Germany’s Angewandte Solarenergie - ASE GmbH that enables Kobe Steel to market ASE’s (now Schott-Solar) Photovoltaic systems in Japan. Kobe Steel is focusing on selling mid- to large-size systems for industrial and public facilities. By 2010, it aims to acquire a 10% share of the domestic market.

Since the beginning of 2002, Kobelco has been supplying Misawa Homes Co., Ltd., with Photovoltaic module systems for its houses. Owing to rising demand, they began manufacturing the modules in November 2001 at the Takasago Works in Hyogo, Japan.

3.5.10 MSK Corporation

MSK Corporation was founded in 1967 as an import/export company for electrical parts. Already in 1981 MSK began with sales of solar cells and in 1984 opened a Photovoltaic module factory in the Nagano Prefecture. In 1992 they concluded a distribution agreement with Solarex (now BP Solar) and at the beginning of the Japanese Residential Dissemination Programme in 1994, MSK developed the roof material “Just Roof”, together with Misawa Homes, and started sales of residential PV systems.

In August 2006, Suntech Power (PRC) announced the first step of its acquisition of MSK. Suntech acquired a two-third equity interest in MSK for $ 107 million (€ 73.86 million) in
cash [Msk 2006]. The second step to acquire the remaining shares was closed in June 2008 [Sun 2008].

3.5.11 YOKASOL
After the takeover of MSK by Suntech Power, employees of MSK’s Fukuoka Plant bought the plant and set it up as a new company named YOKASOL. The company manufactures mono- and polycrystalline silicon modules.

3.5.12 Daiwa House
Since August 1998, Daiwa House has been selling “Whole-Roof Solar Energy System” attached to single-family houses. This system, which is a unique type that comes already fixed to the steel roofing material, uses thin-film solar cells made from amorphous materials.

3.5.13 Misawa Homes
In 1990, Misawa Homes Co. Ltd., one of the biggest housing companies in Japan, started research activities to utilise PV as roofing material. In October 1992 they built the first model of the “Eco Energy House” with a PV roof-top system in the suburbs of Tokyo. In 2003/4 Misawa Homes built “Hills Garden Kiyota”, a 503-home residential community in Kiyota, Hokkaido. The homes are all equipped with solar Photovoltaic systems, with a total electrical generation capacity of 1,500 KW, the world’s largest in terms of electricity generated by a residential development at that time [Mis 2005].

3.5.14 Sekisui Heim
Sekisui Heim is a housing division of the Sekisui Chemical Company, which was founded in 1947. Sekisui Chemical was the first to develop plastic moulds in Japan. In 1971, Sekisui Chemical created the Heim Division to build modular houses. Sekisui Heim, currently the fourth largest house builder in Japan, builds about 15,000 houses per year, of which about 50% are equipped with a solar Photovoltaic system.

In January 2003 Sekisui introduced the “zero-cost-electricity-system” [Jap 2003]. The basic specification of the “utility charges zero dwelling house” are:

1) Use of “creative energy” = solar Photovoltaic electricity generation system;
2) Utilisation of “energy saving” = heat pump and the building frame responsive to the next-generation energy saving standard;
3) Management for “effective operation” = the total electrification by using the electricity in the middle of night.

In its 2009 Annual Report Sekisui stated that they have already sold some 67,000 units with Photovoltaic electricity systems.

3.5.15 PanaHome Corporation
PanaHome Corporation was established in 1963 to support the Matsushita Group’s housing business. On 1 October 2002, the 28 principal subsidiaries of the PanaHome Group merged to form PanaHome. Designating detached housing, asset management, and home remodelling are the three core businesses of the company. In line with this, PanaHome offers Eco-Life Homes that are “friendly to people and the environment”. As a part of this initiative, in July 2003 PanaHome launched the sale of energy-conservation homes equipped with solar power generation systems and other energy saving features.

Matsushita Electric Industrial Co., Ltd., has strengthened its capital alliance with Matsushita Electric Works, Ltd., creating a new comprehensive co-operative framework for the Matsushita Group for the 21st century. As a part of this new Group framework, PanaHome was turned into a consolidated subsidiary of Matsushita Electric Industrial on 1 April 2004.

PanaHome is offering environment-friendly Eco-Life Homes to reduce the volume of CO₂ emissions generated in everyday living, through the use of a solar power generation system, an all-electric system, and the Eco-Life ventilation system.

3.5.16 Tokuyama Corporation
Tokuyama is a chemical company involved in the manufacturing of solar-grade silicon, the base material for solar cells. The company is one of the world’s leading polysilicon manufacturers and produces roughly 16% of the global supply of electronics and solar grade silicon. According to the company, Tokuyama had an annual production capacity of 5,200 tons in 2008 and has expanded this to 8,200 tons in 2009. In November 2008, a plan to build a 3,000 ton factory in Malaysia was presented. The plant should become operational in 2012.

A verification plant for the vapour to liquid-deposition process (VLD method) of Polycrystalline silicon for solar cells has been completed in December 2005 [Tok 2006]. According to the company, steady progress has been made with the verification tests of this process, which allows a more effective manufacturing of polycrystalline silicon for solar cells.

Tokuyama has decided to form a joint venture with Mitsui Chemicals, a leading supplier of silane gas [Tok 2008]. The reason for this is the increased demand for silane gas due to the rapid expansion of amorphous/microcrystalline thin-film solar cell manufacturing capacities.
3.5.17 Additional Silicon Producer

**JFE Steel Corporation:** JFE Steel began to produce silicon ingots in 2001. To stabilise their supplies of feedstock, it began to investigate techniques for producing SOG silicon in-house from metallic silicon as an alternative to polysilicon. Prototypes created with 100% metallic silicon have achieved the same high conversion efficiency as conventional polysilicon units. According to RTS the production capacity in 2008 was about 400 tons and it is planned to increase this to 500 to 1000 tons in the future [Ikk 2009].

**Japan Solar Silicon:** JSS was established in June 2008 as a joint venture between Chisso Corporation, Nippon Mining Holdings (since 1 April 2009 – Nippon Mining & Metals) and Toho Titanium. Currently the company operates a pilot plant and plans to start their commercial plant operation with a capacity of 400 tons in the second half of 2010. An expansion to 3,000 tons is foreseen to begin in 2010 as well.

**M.Setek:** Manufacturer of semiconductor equipment and monocrystalline silicon wafers. The company has two plants in Japan (Sendai, Kouchi) and two in the PRC, Hebei Lang Fang Songgong Semiconductor Co. Ltd. (Beijing) and Hebei Ningjin Songgong Semiconductor Co. Ltd. (Ningjin). In April 2007 polysilicon production started at the Soma Factory in Fukushima Prefecture. According to the company, the current production capacity is 3,000 tons.

**Mitsubishi Materials Corporation (MMC):** The company was established in 1950 and is one of the world’s largest diversified materials corporations. MMC produces polysilicon for the semiconductor and Photovoltaic industry. Current production capacity is about 3,300 tons with a further expansion underway. The first 1,000 ton phase should become operational win 2010 with further ramp up to 2,800 tons possible. About 1,500 tons of polysilicon are produced by their affiliates Mitsubishi Polycrystalline Silicon Corp. and Mitsubishi Polycrystalline Silicon America Corp.

**NS Solar Material Co., Ltd.:** This is a joint venture between Nippon Steel Materials and Sharp Corporation and was established in June 2006. Production was planned with 480 tons/year and start of operation was scheduled for October 2007.

**OSAKA Titanium Technologies Co. Ltd.** is a manufacturer of Titanium and Silicon. The first step of the capacity increase from 900 tons to 1,300 tons was completed in May 2007 [Sum 2007]. The second increase to 1,400 tons/year should be completed in October 2008. In addition, a new plant with 2,200 tons will be constructed and should become operational in 2011.
4. People’s Republic of China

The production of solar cells and the announcements of planned new production capacities in the People’s Republic of China have sky-rocketed since 2001. Production rose from just 3 MW in 2001 to 1070 MW in 2007 and for 2008 the estimates vary between 2.3 and 2.9 GW. For 2009, capacity increases to 8.9 GW have been announced, whereas the figure stands at 12.3 GW for 2010. In parallel, China is aiming to build up its own polysilicon production capacity. The numbers given for 2007 production capacity vary quite significantly from 1,225 [Pvn 2008] to 4,550 [Cui 2007] and 8,900 [Yol 2008]. The same is true for the 2010 figures: 29,050 [Pvn 2008] to 84,500 [Cui 2007]. However, despite the discrepancies, it is clear that there is a strong drive for building up its own silicon feedstock supply industry. This development has to be seen in the light of the PRC’s strategy to diversify its energy supply system and overcome the existing energy shortage.

Why is this of particular interest? During the China Development Forum 2003, it was highlighted that China’s primary energy demand will reach 2.3 billion toe in 2020 or 253% of the 2000 consumption if business-as-usual (BAU) occurs [Fuq 2003]. Under such a scenario the electricity demand would be 4,200 TWh by 2020 (Fig. 10).

This development presents a reason to press for additional Government policies supporting the introduction of energy efficiency measures and renewable energy sources. With the proposed measures, fossil energy demand would still grow, though considerably slower than in the case of BAU.
The Standing Committee of the National People’s Congress of China endorsed the Renewable Energy Law on 28 February 2005. At the same time as the law was passed, the Chinese Government set a target for renewable energy to contribute 10% of the country’s gross energy consumption by 2020, a huge increase from the current 1%. The Renewable Energy Law went into effect on 1 January 2006, but no specific rate was set for electricity from Photovoltaic installations. The 2006 Report on the Development of the Photovoltaic Industry in China, by the National Development and Reform Commission (NDRC), the Global Environment Facility (GEF) and World Bank (WB), estimates a market of 130 MW in 2010 [NDR 2006]. The report states that the imbalance between solar cell production and domestic market development impedes not only the sustainable development of energy sources in China, but also the healthy development of the PV industry.

In the National Outlines for Medium and Long-term Planning for Scientific and Technological Development (2006-2020), solar energy is listed as a priority theme.

**New and renewable energy technologies:** to develop low-cost, large-scale renewable energy development and utilisation technologies, large-scale wind power generation equipment; to develop technology of Photovoltaic cells with high cost-effect ratio and its utilisation; to develop solar power generation technology and study integration of solar powered buildings; to develop technologies of fuel cells, hydropower, biomass energy, hydrogen energy, geothermal energy, ocean energy, biogas, etc.

Also the National Medium-and-Long Term Renewable Energy Development Plan has listed solar Photovoltaic power generation as an important developing point. Within the National Basic Research Programme of China, the so-called 973 Programme, there is an additional topic on “Basic research of mass hydrogen production using solar energy”.

With the support from national ministries and commissions, the top efficiency of China’s current lab PV cell is 21%, commercialised PV components and normal commercialised cells respectively have an efficiency of 14 – 15% and 10 – 13%. China has reduced the production cost of solar PV cells and the price of solar cells has gradually declined from the 40 RMB/Wp (4.40 €/Wp) in 2000. In July 2009, the National Energy Administration (NEA) has set a subsidised price for solar power at 1.09 RMB/kWh (0.112 €/kWh) in 2010/11, this will be within the cost price of routine power generation.

At the moment, the companies need between 1.3 and 1.5 RMB/kWh (0.134 and 0.155 €/kWh) to become profitable. Therefore, the Institute is calling on the Government to adjust the prices to accelerate the domestic market growth. When the electricity generation cost with solar PV systems declines to some 1 RMB/kWh (0.103 €/kWh) in 2010/11, this will be within the cost price of routine power generation.

In 21 July 2009 a joint notice was release by the Ministry of Finance, Ministry of Science and Technology and the National Energy Administration announcing subsidies for PV demonstration projects in the following two to three years through a programme called “Golden Sun”. The Government will subsidize 50% of total investment in PV power generation systems and power transmission facilities in on-grid projects, and 70% for independent projects, according to the notice. The available budget should allow about 500 MW of PV installations.

A new plan to foster the development of “new energy” sources, including wind, solar and nuclear is expected to be published by the end of this year. According to statements of senior Government officials published in various Chinese media, investment in new energy under this Energy Revitalization Plan will reach more than RMB 3 trillion (€ 309 billion) and investments in smart-grids will exceed RMB 4 trillion (€ 436 billion) by the next decade.

### 4.1 PV Resources and Utilisation

The PRC’s continental solar power potential is estimated at 1,680 billion toe (equivalent to 19,536,000 TWh) per year [CDF 2003]. One percent of China’s continental area, with 15% transformation efficiency, could supply 29,304 TWh of solar energy. That is 189% of the world-wide electricity consumption in 2001.

The Standing Committee of the National People’s Congress of China endorsed the Renewable Energy Law on 28 February 2005. Although the Renewable Energy Law went into effect on 1 January 2006, the impact on Photovoltaic installations in China is however still limited, due to the fact that no tariff has yet been set for PV. The main features of the Law are listed below:

- Energy Authorities of the State Council are responsible for implementing and managing renewable energy development, including resource surveys;
The Government budget establishes a renewable energy development fund to support R&D and resource assessment;

The Government encourages and supports various types of grid-connected renewable energy power generation;

Grid enterprises shall purchase the power produced with renewable energy within the coverage of their power grid, and provide grid-connection service;

The grid-connection price of renewable energy power generation shall be determined by the price authorities, and the excess shall be shared in the power selling price within the coverage of the grid;

The Law became effective in January 2006.

During the China Renewable Energy Development Strategy Workshop 2005, Wang Sicheng, from the National Development and Reform Commission’s Energy Institute, presented the “Strategic Status of Photovoltaics in China” [Sic 2005]. The national target for the accumulated capacity of PV systems set in the «Eleventh Five-Year Plan» (2006 – 2010) was 500 MW in 2010. The predictions of the PV Market in China for 2020 were rather optimistic. The accumulated installed capacity was given as 30 GW and included 12 GW in the frame of the Chinese Large-Scale PV Development Plan, a project which was scheduled to start in 2010. However, due to the fact that at that time this plan did not receive official consideration the actual growth of PV installations was far below the required figures.

Therefore, the 2007 China Solar PV Report authored by the China Renewable Energy Industry Association, Greenpeace China, European PV Industry Association, and WWF, reduced the market predictions to 300 MW cumulative installed capacity in 2010 [Chi 2007]. For 2020, two scenarios are given. The low target scenario predicts 1.8 GW, in line with the old Government policy, whereas a high target of 10 GW would be possible if strong support mechanisms were to be introduced.

In May 2009, SEMI’s PV Group published a White Paper entitled “China’s Solar Future” [Sem 2009a]. China faces a rapidly increasing demand for energy, and the country is building a massive PV industry, representing all facets of the supply chain, from polysilicon feedstock, ingots and wafers to cells and modules. The report recommends an accelerated adoption of PV generated electric power in China to reach global average level of PV power generation by 2014.

The main policy recommendations of the report are:

- Establish clear targets for PV installation. Adjust current national targets and achieve global average level by the year 2014, including adjustment of the 2010 target from 300MW to 745MW and the 2020 target from 1.8GW to 28GW.

- Enact clear and easy-to-administer PV incentive policies that are suitable for China’s unique situations, using both market and legal mechanisms to encourage private investment in PV.

- Maintain the current rural electrification effort but priority should be given to grid-connected large scale power plants and building integrated systems.

Fig. 11: Cumulative installed Photovoltaic capacities in PRC, the old and new targets for 2010/11 and 2020 and the needed annual growth rates.
Immediately implement a Government financed direct investment subsidy model at central and local levels, and effectively implement feed-in tariff programmes stipulated in the Renewable Energy Law.

The White Paper also points out that despite the economic and social benefits of increasing solar power demand, China’s lack of PV demand might threaten Government solar incentives in other countries. Policy-makers in Europe, US and elsewhere may view China as the primary beneficiary of domestic economic policies that encourage PV demand, while China itself is not contributing to global fossil fuel reduction.

On 1 November 2006 a new law on energy-efficient construction, in order to promote the use of solar power to supply hot water and generate electricity, took effect in the city of Shenzhen18. Projects which are unable to use solar power will require special permission from the Government otherwise they cannot be put on the market. By 2010, the Shenzhen Construction Bureau expects that 50% of the new buildings will install solar water heating systems and 20% of new buildings will use Photovoltaic electricity generation systems.

China’s RMB 4 trillion stimulus package included RMB 210 billion (€ 21.6 billion) for green energy programmes as announced in early March 2009. On 23 March 2009 the Chinese Ministry of Finance and Ministry of Housing and Urban-Rural Development [Mof 2009] announced a solar subsidy programme which immediately went into effect. It was suggested that 70% of the budget would be handled by the Provincial Finance Ministries. For 2009 the subsidy will be 20 RMB/Wp (2.06 €/Wp) for BIPV and 15 RMB/Wp (1.46 €/Wp) for roof top applications. The document neither mentions a cap on individual installations nor a cap for the total market. The subsidy will be paid as a 70% down payment and 30% after the final acceptance of the project.

Eligible are all systems >50kW which have module efficiencies of >14% (polycrystalline modules), >16% (monocrystalline modules), or >6% (thin-film). Applications for grants apparently have to be made from 15 May to 30 August. However, public comments from an official of the National Development and Reform Commission (NDR) indicate that issues like grid connection are not yet discussed sufficiently. One of the reasons is that none of the Ministries which announced the subsidy has jurisdiction over the grid.

In addition to the solar subsidy programme which was announced on 23 March 2009 by the Chinese Ministry of Finance and Ministry of Housing and Urban-Rural Development [Mof 2009], Mof announced another support programme – the Golden Sun Programme – for pilot cities to support the use of renewable energies in buildings on 21 July 2009.

In April 2009, JLM Pacific Epoch reported that according to China Business News the Jiangsu Province plans to release a new plan to promote solar power applications soon [Jlm 2009]. According to the plan, Jiangsu intends to reach building and rooftop installations of 10MW in 2009; 50MW including 40MW of rooftop projects in 2010; and 200MW including 180MW of rooftop projects in 2011. The plan also mentions the possibility of establishing funds to provide project construction subsidies and risk guarantees, an executive of Jiangsu’s PV Industry Association stated. The plan stipulates further allocations of quotas to local companies.

A number of large scale Photovoltaic projects, ranging up to 1 GW were announced in the course of the last 18 months in China. How many of them will actually be realised to create a local market for solar Photovoltaic electricity systems, still has to be seen.

With all these measures a doubling or even tripling of the market seems possible in 2009, as a starting point for the development of a GW size market from 2012 on. China is now aiming for 2 GW total installed solar capacity in 2011. In July 2009 the new Chinese energy stimulus plan revised the 2020 targets for installed solar capacity to 20 GW (Fig. 11).

4.2 Solar Companies

In the following chapter, some of the major market players in the PRC are briefly described. This listing is far from being complete, due to the fact that more than 50 solar cell and more than 300 solar module companies exist in China. In addition, availability of information or data for some companies is very fragmentary.

4.2.1 Canadian Solar Inc.
Canadian Solar Inc. was founded in Canada in 2001 and was listed on NASDAQ in November 2006. CSI has established six wholly-owned manufacturing subsidiaries in China, manufacturing ingot /wafer (planned production in mid 2008), solar cells and solar modules. According to the company it achieved 120-150 MW of ingot and wafer capacity and 270 MW of cell capacity in 2008. For 2008 the company reported shipments of 167.5 MW.

4.2.2 Changzhou EGing Photovoltaic Technology Co. Ltd.
The company was founded in 2003 and works along the complete Photovoltaic industry value chain, from the produc-
tion of mono-crystalline furnace, quartz crucible, 5-8 inch mono-crystalline silicon ingots supporting equipment of squaring and wire sawing, mono-crystalline silicon wafers, solar cells, and solar modules. According to the company, it has a production capacity of over 200MW across the complete value chain of ingot, wafer, cell and modules.

4.2.3 China Sunergy (formerly CEEG Nanjing PV-Tech Co. Ltd.)
China Sunergy was established as CEEG Nanjing PV-Tech Co. (NJPV), a joint venture between the Chinese Electrical Equipment Group in Jiangsu and the Australian Photovoltaic Research Centre in 2004. China Sunergy went public in May 2007. At the end of 2008, the Company had five selective emitter (SE) cell lines, four HP lines, three capable of using multi-crystalline and mono-crystalline wafers, and one normal P-type line for multi-crystalline cells with a total name-plate capacity of 320MW. For 2008 a production of 111 MW was reported by the company.

4.2.4 JA Solar Holding Co. Ltd.
JingAo Solar Co. Ltd. was established in May 2005 by the Hebei Jinglong Industry and Commerce Group Co. Ltd., the Australia Solar Energy Development Pty. Ltd. and Australia PV Science and Engineering Company. Commercial operation started in April 2006 and the company went public on 7 February 2007. According to the company, the production capacity should increase from 600 MW at the end of 2008 to 875 MW at the end of 2009. For 2008 the company reported shipments of 277 MW.

4.2.5 Jetion Holdings Ltd.
The group was founded in December 2004, went public in 2007, and manufactures solar cells and modules. According to the company, production capacity is 100 MW for solar cells and 60 MW for modules at the end of 2008. For 2008 the company reported a production of 65 MW solar cells. For 2008 shipments of 45 MW modules (made from own cells) and 19.6 MW of cells were reported.

4.2.6 NingBo Solar Electric Power Co. Ltd.
The company has been part of China PuTian Group since 2003. According to company information Ningbo has imported solar cell and module producing and assembling lines from America and Japan. According to the company, production capacity will be increased in 2009 from the current 200 MW to 350 MW.

4.2.7 Shanghai Solar Energy Science & Technology Co. Ltd.
SSEC produces mono-crystalline and multi-crystalline solar cells. According to the company, current production capacity is 80 MWp and it is planned to increase it to 100 MW by 2010.

4.2.8 Shanghai TopSolar Green Energy Ltd.
Shanghai TopSolar Green Energy Co., Ltd is a joint stock company established by Shanghai Electric Group Holding Co., Ltd, Shanghai Jiao Da NanYang Co. Ltd, and Shanghai Zhenglong Technology Investment Co. Ltd. Current production capacity is 300 MW according to the company.

4.2.9 ShanShan Ulica Science & Technology Co. Ltd.
ShanShan Ulica Science & Technology Co., Ltd, was founded in August 2005 as a joint venture between the ShanShan Group and Shanghai Ulica Solar Company. It is planned to increase the current production capacity from 20 MW to 100MW, but no date is set for it.

4.2.10 Shenzhen Topray Solar Co.Ltd.
The company was founded in 2002 and manufactures solar cells, solar chargers, solar lights, solar garden products and solar power systems, as well as solar charge controllers, solar fountain pumps and solar fan caps. For 2008 the company reported production capacities of 50 MW for dual junction amorphous silicon solar cells and 30 MW for mono and poly crystalline solar cells.

4.2.11 Solarfun Power Holdings
Solarfun was established in 2004 by the electricity metre manufacturer Lingyang Electronics. The first production line was completed at the end of 2004 and commercial production started in November 2005. The company went public in December 2006 and reported the completion of their production capacity expansion to 360 MW in the second quarter of 2008. For 2009 a further 60 MW expansion is planned. For 2008 total module shipments of 172.8 were reported by the company.

4.2.12 Suntech Power Co. Ltd.
Suntech Power Co. Ltd. is located in Wuxi. It was founded in January 2001 by Dr. Zhengrong Shi and went public in December 2005. Suntech specialises in the design, development, manufacturing and sale of Photovoltaic cells, modules and systems. For 2008 Suntech reported shipments of 497.5 MW and held 2nd place in the Top-10 list. The annual production capacity of Suntech Power was increased to 1 GW by the end of 2008. The takeover of the Japanese PV module manufacturer MSK was completed in June 2008. The company has a commitment to become the “lowest cost per watt” provider of PV solutions to customers world-wide.

4.2.13 Trina Solar Ltd, PRC
Trina Solar was founded in 1997 and went public in December 2006. The company has integrated product lines, from ingots to wafers and modules. In December 2005 a 30 MW mono-crystalline silicon wafer product line went into operation. According to the company the production capacity was
350MW for each of ingot, wafer, cell and modules at the end of 2008. For 2008 shipments of 201 MW were reported.

### 4.2.14 Wuxi Shangpin Solar Energy Science & Technology Co. Ltd.
This is a UK invested company which specialises in R&D, manufacturing and sales of crystalline silicon solar cells, modules and PV powered products. According to the company, the first 25 MW production line was put into operation in April 2007 and the second followed in August 2008. An increase to 100 MW is planned for 2009.

### 4.2.15 Yingli Green Energy Holding Company Ltd.
Yingli Green Energy went public on 8 June 2007. The main operating subsidiary, Baoding Tianwei Yingli New Energy Resources Co. Ltd., is located in the Baoding National High-New Tech Industrial Development Zone. The company deals with the whole set from solar wafers, cell manufacturing and module production. On 29 April 2006 the ground-breaking ceremony was held for Yingli’s 3rd phase enlargement project, which aimed for production capacities of 500 MW for wafers, solar cells and modules at the end of 2008. The investment included a Photovoltaic System Research Centre and a Professional Training Centre as well. The first stage of this expansion to 200 MW was finished in July 2007 and the company reported that the expansion to 400 MW was done in the second half of 2008 and the expansion to 600 MW in the middle of 2009 is on track. The financial statement for 2008 gave shipments of 281.15 MW.

### 4.2.16 Yunnan Tianda Photovoltaic Co. Ltd.
The Yunnan Tianda Photovoltaic Co. is one of the oldest companies which make, design, sell and install solar modules and PV systems in China and was founded in 1977 as Yunnan Semi-Conductor Device Factory. In 2005, the production capacity of solar cells was extended to 35MW and the production of 5 inch solar cells started. In 2006 the capacity was increased to 60MW and in 2007 the production capacity of solar cells was extended to 100MW. In April 2009 the company reported the signature of agreements with the Jiaxing Xiuzhou Industrial Park Management Committee to build a production facility with an aim of 100 MW/year in the first stage and 200 MW in the final stage.

### 4.2.17 Additional Solar Cell Companies

- **Aide Solar** (Jiangsu Aide Solar Energy Technology Co. Ltd.) was founded in 2003 and formed a joint venture with the Taiwanese Panjit Group in November 2007. The company has a mono solar cells production line with 20 MW capacity and increased their solar modules production capacity to 150 MW in 2008. In 2009 an expansion to 200 MW module capacity and 80 MW cell capacity is foreseen.

- **Astronergy** (Chint Solar Energy Science & Technology Co. Ltd.) was established as a member of the Chint Group in October 2006. The first production line of 25 MW for crystalline silicon cells and modules was installed in May 2007 and an increase of the production capacity to 100 MW was finished in July 2008. The company not only plans to reach 380 MW production capacity by 2010, but to “become the world’s leading thin-film PV producer”. On 3 July 2008 Oerlikon Solar announced that Chint Solar purchased a micromorph® R&D line and first-phase production equipment with plans to build the production capacity up to 180 MWp in 2010.

- **Baoding TianWei SolarFilms Co. Ltd.** was set up in 2008. It is a subsidiary of Baoding TianWei Group Co., Ltd., a leading company in the China power transformer industry. In Phase I of the production, the set up has a capacity of 50MW and should begin commercial operation in the second half of 2009. The company plans to reach a capacity of 500MW in 2015.

- **Best Solar Hi-Tech Co. Ltd.** was set up by LDK Solar’s founder and CEO Xiaofeng Peng and started operations in February 2008. The company aims to produce amorphous/ microcrystalline silicon thin-film modules and has contracted AMAT for the equipment. The ground-breaking for their “Site 1 in JiangSu SuZhou took place in February 2008. With an investment of 2.5 billion $ it has a design capacity of 1 GW to be realised in three phases. It is planned to start solar cell production in the 3rd Quarter of 2009. At their second site in JiangXi NanChang, also with a design capacity of 1 GW, ground-breaking took place in June 2008.

- **ENN Solar Energy** (part of XinAo Group) was set up in the Langfang Economic and Technological Development Zone in 2007. In November 2007 ENN Solar Energy signed a contract with AMAT for a SunFab Thin-film production line to produce ultra-large 5.7m² (GEN 8.5) solar modules. The 50 MW line is planned to be the first phase of an expected 500 MW capacity plant. Start of commercial production is planned for the 2nd Quarter of 2009.

- **Nantong Qiangsheng Photovoltaic Technology Co. Ltd.** (QS Solar, Shanghai, China) started the production of amorphous silicon thin-film solar with their new 25 MW production line in January 2008. The company announced that it would add two more production lines in 2008, bringing the total production capacity to 75 MW. The company plans to increase production capacity
within the next three years to 500 MW.

- **Shanghai Chaori Solar Energy Science & Technology Co. Ltd.** was established in June 2003. Production capacity was 15 MW in 2007 and the company planned to increase it to 40 MW in 2008.

- **Solar EnerTech Corp.** is incorporated in the USA, but its factory is based in Shanghai, China. Solar EnerTech has established a manufacturing and research facility in Shanghai’s Jingqiao Modern Science and Technology Park. According to the company, production capacity was 50 MW of solar cells and modules at the end of 2008.

- **TaiZhou Sopray Solar Co. Ltd.** was established in 2005 as a joint venture between Taizhou Luqiao Huanneng Lights Factory and Mr. Michael Ming. According to the company the annual output capacity of mono- and polycrystalline solar cells is 100MW, with plans to double to 200 MW in 2009.

- **Zhejiang Sunflower Light Energy Science & Technology Co. Ltd. (Sunowe)** was funded by Hong Kong YauChong International Investment Group Co. Ltd., founded in 2004 in Shaoxing, Zhejiang. In a first phase it is planned to ramp up the annual production capacity to 100MW. According to the company, 75 MW are already operational.

### 4.3 Polysilicon, Ingot and Wafer Manufacturers

In the following chapter, some of the major market players in the PRC are briefly described. This listing is far from being complete, due to the fact that at the moment there are a large number of start-up activities. In addition, availability of information or data for some companies is very fragmentary.

#### 4.3.1 GCL Silicon Holdings, Inc.

The company was founded in March 2006 and started the construction of their Xuzhou polysilicon plant (Jiangsu Zhongneng Polysilicon Technology Development Co. Ltd.) in July 2006. Phase I has a designated annual production capacity of 1,500 tons and the first shipments were made in October 2007. Full capacity was reached in March 2008. Phase II, with additional 1,500 tons, started commercial operation in July 2008 and reached full capacity by the end of 2008. Construction for Phase III with 15,000 tons was started in December 2007 and commercial production started one year later in December 2008. Full capacity of all three plants, with a total capacity of 18,000 tons, is expected for the end of 2009. A further expansion to 24,000 tons is planned to be finished in 2010.

In August 2008 a joint-venture Taixing Zhongneng (Far East) Silicon Co. Ltd. started pilot production of trichlorsilane. Phase I will be 20,000 tons to be expanded to 60,000 tons in the future.

#### 4.3.2 EMEI Semiconductor Material Factory

EMEI is a subsidiary of Dongfang Electric Corp., located in Chengdu, and produces and markets semiconductor material silicon. One factory in Emeishan City has an annual production capacity of 200 tons. A second production line in Leshan with an annual polysilicon production capacity of 1,500 tons was scheduled to be completed at the end of 2008. For 2008 a production of 500 tons was reported.

#### 4.3.3 LDK Solar Co. Ltd.

Jianxi LDK Solar Hi-Tech Co. Ltd. was set up by the Liouxin Group, which had 12,000 employees in 2005. The Liouxin Group makes personal protective equipment, power tools and elevators. With the formation of LDK Solar, the company is diversifying into solar energy products. LDK Solar went public in May 2007. According to the company the production capacity for solar wafers at the end of the 2008 was 1.46 GW. Further expansion plans foresee the production capacity growing to 2 GW at the end of 2009 and 3.2 GW in 2010. In 2008 the company announced that they completed the construction of and commenced polysilicon production in their 1,000 metric tons polysilicon plant. Further expansion with a 15,000 metric ton plant is underway and the company expects that the first phase of 5,000 metric tons reach mechanical completion at the end of the second quarter of 2009. Target output for 2009 is 2,000 and 3,000 metric tons of polysilicon.

#### 4.3.4 ReneSola Ltd.

ReneSola, previously known as Zhejiang Yuhui Solar Energy Source Co. Ltd, was listed on London’s AIM Stock Market on 8 August 2006. ReneSola’s factories are based in China, but the company is registered in the British Virgin Islands. ReneSola is recycling silicon to make the wafers. In 2008 ReneSola completed and commissioned 50 MW of multicrystalline ingot and wafer capacity in the fourth quarter of 2008, achieving its annualised ingot production capacity target of 645 MW. Approximately 325 MW of the current capacity is monocrystalline and 320 MW is multicrystalline. The company expects to achieve a wafer manufacturing capacity of 825 MW by July 2009 and the implementation of additional production capacity expansion will be determined by market demand.

In March 2008 the company announced that it had increased
the planned annual polysilicon manufacturing capacity to 3,000 tonnes at the wholly-owned facility in Meishan, Sichuan Province, China. According to the 4th Quarter 2008 financial statement, construction of the polysilicon facility remains on schedule with many facets nearing or having reached completion. Piping, wiring and equipment installation is in progress with much of it in testing phase. Pipe rack transmission systems are complete and ready for testing. Construction of the trichlorosilane distillation towers and the control building are completed. Phase 1 of the facility is expected to reach mechanical completion in the middle of 2009 and Phase 2 mechanical completion is expected around the end of third quarter of 2009. Each phase will have annualised production capacity of 1,500 tons of polysilicon.

4.3.5 Additional Solar Silicon Companies

- **Chongqing Daqo New Energy Co. Ltd.** Daqo New Energy is a subsidiary company of Daqo Group and was founded by Mega Stand International Limited in January 2008. The company started to build a high-purity polysilicon factory with an annual output of 3,300 tons in the first phase in Wanzhou. The first polysilicon production line with an annual output of 1,500 tons started operation in July 2008. The second production line is planned to be completed in March 2009. It is planned to expand the production capacity to about 10,000 tons by the end of 2010 and 15,300 tons by 2011.

- **China Enfi Engineering Corporation** is an engineering company established by China Nonferrous Engineering and Research Institute. With ENFI’s own technology a polysilicon project was set up. **Luoyang China Silicon Hi-tech Corporation**, which is the controlling subsidiary, was in charge of Phase I of the polysilicon project with an annual yield of 300 tons. The plant foundation was laid in June 2003 and the plant was put into operation in October 2005. The Phase II expansion project had an annual yield of 1,000 tons polysilicon and became operational in February 2007. Phase III with 2,000 tons plans to increase it’s capacity to 500 tons.

- **Niking Technology Co. Ltd.** was founded in 1998 and engaged in scientific research and purified polysilicon. According to the company their polysilicon plant construction has been completed. In 2008 a production of 300 tons of polysilicon was reported and the company plans to increase its capacity to 500 tons in 2009.

- **Luoyang Zhonggui Material Co. Ltd.** The company is a joint venture of the American MEMC Company and the Chinese Sijia Semiconductor Company. The main products are multi-crystal silicon, single-crystal silicon and organic silicon. The production capacity is 500 tons and it is planned to increase it to 2000 tons.

- **Le Shan LEDIAN Tianweili Silicon Science and Technology Co. Ltd.** is a joint venture formally set up in January 2008 by Baoding Tianwei Baobian Electric Co. Ltd. and Le Shan Electric Power Co. Ltd. The company will build a polycrystalline facility at Le Shan of Sichuan province, with a capacity of 3000 t/a.

- **Nan’an Sanjing Silicon Refining Co., Ltd.** was established in 1996. The corporative company includes Taining Sanjing Silicon Smelting Co. Ltd., Dehua Longtengfei Smelting Co. Ltd. and Xiamen Sunhope Silicon Products Co. Ltd. The company is engaged mainly in crude metal silicon mining, primary smelting, purification, refinement, exporting and its R&D. It presently possesses an annual processing capacity of approximately 40,000 tons of metal silicon.

- **CSG Holding Co. Ltd.**, a Chinese glass producer is building up the complete silicon wafer based Photovoltaics value-chain. **Yichang CSG Polysilicon Co. Ltd.** was established in 2006 and is located in the Xiaoting District, Yichang City, Hubei Province. This polysilicon project is divided into three stages with unified planning of 4500 to 5000 tons per year of high-pure polysilicon. The first stage with 1500 tons/year was started on 22 October 2006 and put into operation at the end of 2008. Dongguan CSG Solar Glass Co. Ltd., was founded in October 2005 and is now operating two production lines for solar glass. An additional sub-company “CSG PVTECH CO. LTD” was founded in February of 2006, which started the pilot production of solar cells on a 25 MW line in June 2007. The main products are silicon solar cells and modules with a planned capacity of 450MW by 2010.

- **DALU New Energy Company** is a subsidiary of DALU Industrial Investment Group established in 1993. The company plans a polysilicon production plant with a total capacity of 18,000 tons. The construction of the plant will be executed in three phases, i.e. Phase I: 2,500 t/a P; Phase II: 5,000 t/a and Phase III: 10,000 t/a.

- **Sichuan Xinguang Silicon Technology Co. Ltd.** constructed a production plant for silicon material and began commercial operation in February 2007. For 2007 a production of 230 tons and for 2008 a production capacity of 1,500 tons were reported.
Sichuang Yongxiang Co. Ltd. was jointly established by the Tongwei Group and Giant Star Group in 2002. In July 2006, Leshan Yongxiang Silicon Co. Ltd. was established as a subsidiary. The company operates a 5,000 tons/year production of trichlorosilane. In July 2007 the construction of a polysilicon plant with 1,000 tons/year capacity started with the total investment of RMB 5 billion. A further expansion of 10,000 tons/year polycrystalline silicon is planned. Current production is 1,000 tons/year.

Wuxi Zhongcai Technology Co. Ltd. (http://www.wxzhongcai.com) is a subsidiary of Wuxi Zhongcai Group and was founded in 2006. The company has a 300 tons/year multicrystalline silicon production line (modified from Siemens technology).

Yaan Yongwang Silicon Industry Co., Ltd. is a subsidiary of the Hong Kong based Yongwang Silicon Industry Investment Co. The company is located in Yaan Industry Park an area with rich hydropower resources. According to the company it started with the trial production of its second 300 ton silicon line at the end of March 2009. The company also started the construction of a 3,000 ton poly-silicon factory and is aiming for 10,000 tons capacity in the long run.

4.3.6 Ingot and wafer Companies

JiangSu Shunda Group Corporation is based in Yangzhou. As a high-technology company it focuses on the Photovoltaic market and produces mono-crystalline ingots, and wafers and solar modules. According to Global Sources in 2009, the company has production capacities of 1,100 tons of silicon ingots, 350 million silicon wafers and 20 MW of solar cells.

Jinglong Industry and Commerce Group Co. Ltd. mainly produces monocrystalline silicon ingots and wafers, but also produces graphite products, quartz crucibles and chemical products. Jinglong produce mono-crystalline silicon mainly for the semiconductor industry, but also for solar cells. At present, Jinglong has an annual capacity of more than 2,600 tons and 80 million wafers. The company plans to increase production capacity to 5,000 tons in 2010.

Jinko Solar Co. Ltd. was founded by HK Paker Technology Ltd in 2006. The company’s main products are silicon wafers. In 2008 the production capacity of the company was approximately 185MW. For 2009 an expansion to 400 MW is planned.

Luoyang Monocrystalline Silicon Co. Ltd. is a State-owned company. The products of the company are: polycrystalline silicon (annual output 300 tons), monocrystalline silicon (annual output 15 tons), organosilicon γ1 (annual output 165 t), and 6-inch silicon polished wafer (annual output 2 million pieces).

Solargiga Energy Holdings Ltd. was incorporated in March 2007 and listed on the Hong Kong Stock Exchange on 31 March 2008. According to the company the annual production ability of silicon ingots was 2000 tons and 56 million pieces of wafers at the end of 2008. For 2009 an increase to 4000 tons and 150 million pieces of wafers is planned.

Xi’an Lijing Electronic Technology Co. Ltd. was founded in December 1997 and is located in the “Western Silicon Valley” Xi’an High-tech Development Zone New Industrial Park. According to the company, production capacity is currently over 100 tons of mono-crystalline silicon and it plans to increase it to 500 tons.

In addition, there are a considerable number of smaller and start-up companies along the whole value chain. However, information is still very fragmented and due to the rapid development quickly goes out of date. In the meantime, an increasing number of consultancies are providing market analysis and study tours. The PRC’s Long-Term Energy Plan calls for a considerable strengthening of the solar industry and all aspects from silicon production, wafering, cell and module manufacturing and distribution are covered. In January 2004 the Ministry of Science and Technology published a solar energy exploitation plan for the next five years, in order to promote the development of Photovoltaic technology and industry.

Chinese manufacturers are expected to export their products as Chinese PV production will grow much faster than the market. In China, Photovoltaics is discussed at the level of a strategic industry policy for the future.
5. Taiwan

In 2002 the Renewable Energy Development Plan was approved by the Executive Yuan and it aimed for 10% or more of Taiwan’s total electricity generation by 2010. This plan led to concerted efforts by all levels of the Government, as well as the general public, to develop renewable energy and to aggressively adopt its use. In 2004, Taiwan enacted “Measures for Subsidising Photovoltaic Demonstration Systems”, as part of its National Development Plan by 2008. This programme provides subsidies that cover up to 50 percent of the installation costs for Photovoltaic systems.

The adopted support scheme foresees a maximum investment subsidy of NT$ 150,000/kWp (3,225 €/kWp)\(^{11}\), but only up to 50% of installation costs. Administration Agencies, public schools and hospitals, suitable for demonstration projects, are eligible for 100 % investment subsidies for systems under 10 kWp. In addition, for all renewable energies, 2 NT$/kWh (0.043 €/kWh) are paid to approved applicants for 10 years, and this can be extended up to 20 years. Other support measures for renewable energies are a 13% tax credit for investment in energy conservation, as well as renewable energy utilisation equipment, a 2-year accelerated depreciation and low interest loans.

The Solar Energy Development Project has a number of long-term goals. It is planned that a total of 7.5 million residents should utilise solar energy by 2030. Industrial and commercial use should be about half that of residential use. Public utilities are expected to have the same solar power generating capacity as the industrial and commercial sectors, and independent solar power generating systems will be set up in mountains and on off-shore islands. The aim is that in 2020, the island’s solar power generating capacity should reach 4.5 GW (1.2 GW PV).

In July 2008, the Cabinet in Taiwan decided to designate solar energy and light emitting diodes (LED) as two industries to actively develop in the near future. The Government was planning to encourage households to install solar panels to generate power and to replace existing public lighting with LED lamps to save electricity.

It is estimated that the two above-industries may generate production value exceeding NT$ 1 trillion (€ 21.5 billion) by 2015. To promote the solar energy industry the Government subsidises manufacturers engaging in R&D and offers incentives to consumers that use solar energy. With the help of official programmes, material suppliers are expanding operations and increasing their investments in the field. In addition, about a dozen manufacturers expressed the intention to invest in fabricating thin-films for solar cells and eight

\(^{11}\) Exchange rate: € 1 = NTD 46.50
of them will set up their own plants to process the products. The solar energy industry may see its output reach NT$ 450 billion (€ 9.68 billion) by 2015.

The Industrial Technology Research Institute (ITRI), a Government-backed research organisation, has drawn up an R&D Strategy for Taiwan with the aim to lower module costs to around 1 $/Wp between 2015 and 2020. The research topics identified range from efficiency increase in the various wafer based and thin-film solar cells to concentrator concepts and novel devices. Despite the fact that the national R&D budget should be doubled within the next four years, it is visible that the main focus is on the industry support to increase production capacities and improved manufacturing technologies.

The Executive Yuan (the Cabinet) passed the “Programme for Coping with Economic Slowdown and Bolstering the Economy” on 11 September 2008. The package covers a total of 41 measures and includes the promotion of solar energy. For 2008 and 2009, the Government set aside NT$ 1 billion (€ 21.5 million) for subsidies to consumers who buy solar-power systems. The Government plans to subsidise half of the installation cost for solar devices, and households which install solar Photovoltaic electricity systems would be offered a favourable electricity rate of 2.1 NT$/kWh (0.045 €/kWh). For 2010 a National Target to double the cumulative capacity installations to 31 MW was set.

On 12 June 2009, the Legislative Yuan gave its final approval to the Renewable Energy Development Act, a move that is expected to bolster the development of Taiwan’s green energy industry. The new law authorises the Government to enhance incentives for the development of renewable energy via a variety of methods, including the acquisition mechanism, incentives for demonstration projects and the loosening of regulatory restrictions. The goal is to increase Taiwan’s renewable energy generation capacity by 6.5 GW to a total of 10 GW within 20 years.

According to Tsai Chin-Yao, Chairman of the Photovoltaic Committee, the law will attract investment of at least NT$ 30 billion (€ 645 million) per year, create at least 10,000 jobs and generate output value of NT$ 100 billion within two years. Tsai recommended setting a price floor of 8 NT$/kWh (0.172 €/kWh) for green energy, as this would give firms a reasonable profit margin.

5.1 Solar Companies

In the following chapter, some of the market players in Taiwan are briefly described. This listing does not claim to be complete, especially due to the fact that the availability of information or data for some companies was fragmentary.

5.1.1 DelSolar Co. Ltd.
DelSolar was established as a subsidiary of Delta Electronics in 2004 and went public in November 2007. DelSolar has a strategic co-operation with the Industrial Technology Research Institute (ITRI), and had a production capacity of 120 MW at the end of 2008 and produced 71.5 MW in 2008 [Pvn 2009]. The company has plans to expand the production capacity to 840 MW by 2012.

5.1.2 E-TON Solartech Co. Ltd.
E-Ton Solartech was founded in 2001 and produced 95 MW in 2008 [Pvn 2009]. At the end of 2008 the production capacity was 320 MW per annum and a capacity increase to 630 MW should be realised at the end of 2010.

5.1.3 Gintech Energy Corporation
Gintech was established in August 2005 and went public in December 2006. In 2008 the company increased its production capacity to 560 MW and had a production of 180 MW [Pvn 2009]. The company plans to expand capacity to 660 MW at the end of 2009 and to 1.5 GW by 2012.

5.1.4 Motech Solar
Motech Solar is a wholly-owned subsidiary of Motech Industries Inc., located in the Tainan Science Industrial Park. The company started its mass production of polycrystalline solar cells at the end of 2000 with an annual production capacity of 3.5 MW. The production increased from 3.5 MW in 2001 to 272 MW in 2008. With this output, Motec Solar was No. 8 of the Top-10 list for 2008. Production capacity should reach 600 MW at the end of 2009. In August 2007, Motech Solar’s Research and Development Department was upgraded to Research and Development Centre (R&D Centre), with the aim not only to improve the present production processes for wafer and cell production, but to develop next generation solar cell technologies [Mot 2007].

5.1.5 Neo Solar Power Corporation
The company was founded in 2005 by PowerChip Semiconductor, Taiwan’s largest DRAM company, and went public in October 2007. The current production capacity of silicon solar cells is 210 MW and a further expansion to 700 MW is already underway. In 2008 the company had shipments of 102 MW [Pvn 2009].
5.1.6 Additional Taiwanese Companies

- **Auria Solar Co.** was founded in October 2007 as a joint venture between E-Ton Solar, Lite-On Technology Corp, Hermes-Epitek Corp. and MiTAC-SYNEX Group to manufacture thin-film solar cells. The company has chosen Oerlikon as equipment supplier and plans to produce amorphous/micromorph silicon thin-films. The first factory will have a capacity of 60 MW and pilot production started at the end of 2008. Further expansion plans aim for 500 MW in 2012.

- **BeyondPV Co. Ltd**’s main shareholder is optical film maker Efun Technology and plans to produce amorphous/microcrystalline silicon thin-film modules. The company is expected to complete their equipment installation in the fourth quarter of 2008, and annual capacity will reach 40MWp by 2010, to be ramped up to 80MWp by 2011, and 350MWp by 2014, according to the parent company.

- **Big Sun Energy Technology Incorporation** was founded in 2006 and started its solar cell production in the 3rd Quarter of 2007 [Dig 2007]. According to the company the production capacity in 2007 was 30 MW and increased to 90 MW.

- **Chi Mei Energy Corp.** is a subsidiary of Chi Mei Opto-electronics (CMO), a world leader in the production of TFT-LCD (Thin-film Transistor Liquid Crystal Display) panels for a wide range of application. Chi Mei Energy was established in January 2008 and completed its equipment installation in Q4, 2008. The start of mass production was Q1, 2009 with 50MW annual capacity. After 2009, Chi Mei Energy plans an aggressive capacity expansion to the GW scale.

- **Ever Energy Co. Ltd.** was established in October 2005 by a group of investors. In early 2007, Ever Energy signed a contract with Centrotherm AG, Germany, to purchase equipment with 90MW capacity for the initial phase of a 180MW facility. In October 2007 the company started to build the factory.

- **Formosun Technology Corporation** was established in 2005 as a trading company of solar cell materials and products. In 2006 they decided to start the production of amorphous silicon thin-film modules with production equipment from EPV (NJ), USA. According to the company, series production started in May 2008 and it is planned to double the capacity to 12 MW in 2009.

- **Green Energy Technology (GET)** was founded as a subsidiary of the Tatung Group of companies in Taiwan and went public in 2008. GET’s initial capacity in May 2005 was 25 – 30 MW wafers with 13 furnaces, band saws, and wire saws. An additional 7 furnaces were installed in July 2006, boosting annual capacity to 40 – 50 MW. In 2008, GET has expanded to 80 furnaces and has now an annual capacity of up to 200 MW wafer production. The company purchased a fully-integrated thin-film solar cell production line with a nominal rated capacity of 50 MW from Applied Materials and started mass production in December 2008. Full capacity is expected to be reached in the 4th Quarter 2009.

- **Higher Way Electronic Co. Ltd.** is an IC application design company established in 1991, which manufactures GaAs and silicon solar cells. The focus is mainly on consumer products.

- **Jenn Feng Co.,Ltd.** was incorporated in 1975. The company plans and installs solar systems. They plan to start a CIGS thin-film production with 12 MW in 2009.

- **Kenmos Photovoltaic** was founded as a joint venture of Kenmos Technology Co. Ltd., NanoPV Corporation and a Taiwanese equipment manufacturer in September 2007. Kenmos PV set up a 10 MW amorphous silicon thin-film production capacity and started mass production in February 2009. The capacity will be expanded to 30 MW in 2009.

- **Millennium Communication Co. Ltd.** manufactures III–V compound material solar cells like GaAs, InGaP single junction and GaAs/InGaP tandem solar cells with up to 25% efficiency.

- **Mosel Vitelic Inc.:** The Group’s principal activities are the design, research, development, manufacturing and sale of integrated circuits and related spare parts. As part of a five-year transformation project, the company moved into the solar cell business in 2006. According to the company, current production capacity is 60 MW. The ground-breaking for a further expansion with 200 MW capacity took place in May 2008. Mosel also plans to develop thin-film solar cell production from its own technology and to expand production capacity to 1.5 GW by 2014.

- **Nexpower Technology Corporation** was formed by United Microelectronics Corporation (UMC) in 2005. UMC is one of the world-wide IC foundry providers.
In addition to crystalline silicon solar cells, Nexpower is dedicated to silicon thin-film Photovoltaics technology and commercial applications, by building up a new manufacturing facility in Hsin Chu, Taiwan with an annual production capacity of 25MW in 2008. The company contracted ULVAC, Japan, for the production equipment [Ulv 2007]. According to the company they have a production capacity of 100 MW.

- **Powercom Co. Ltd.** was founded in 1987, as a provider of power protection products. In 2007 the company installed a 30MW silicon solar cell production line. A future capacity increase to 90MW is planned.

- **Solartech Energy Corp.** (Solartech) was founded in June 2005. Solartech expanded its production capacity from 60 MW to 180 MW in 2008. Further expansion plans aim at a capacity beyond 1 GW per year by 2014.

- **Sunner Solar Corporation** was founded in Taoyuan, Taiwan in June 2007. The company started their pilot production in March 2009 and plan to start mass production of thin-film amorphous silicon modules in the second half of 2009 with 25 MW capacity. The company then plans to expand to 200 MW by 2010.

- **Sunwell Solar Corporation**, a subsidiary of CMC Magnetics Corporation, Taiwan’s top compact disc maker, contracted a 45 MW thin-film PV production plant with Oerlikon Solar. The plant started production at the beginning of September 2008. According to Oerlikon, Sunwell has placed a follow-up order of 180 MW and plans to start production in 2009 [Oer 2008].

- **Tainergy Tech Company Ltd.** was founded in 2007. According to the company, production capacity was 60MW in 2008 and in 2009 total production capacity will be increased to 240MW.

- **Topco Scientific**, is a semiconductor company and Taiwan’s largest distributor of silicon wafers. In 2005 the company started to produce wafers for solar cells from reclaimed semiconductor material. In 2006 the company announced that it would stop the manufacturing of silicon solar cells and move to thin-film solar cells.

- **Top Green Energy Technologies Inc.** was established in January 2006 by Powercom. The company produces silicon solar cells and invested in the upstream polycrystalline silicon production with a modified Siemens manufacturing process. They broke ground for the factory at “Chang Pin Industrial Park” in May 2009.

- **United Printed Circuit Board (UPCB)** started the construction of its first solar cell factory at the high-tech industrial park in Yilan County of Eastern Taiwan in August 2007. The first stage is a 30 MW multi-crystal silicon line from Centrotherm, Germany. According to the company, production will increase from the current 30 MW to 80 MW in 2009, 180 MW in 2010 and 270 MW in 2011.
6. The United States

In 2008, the USA was the third largest market with 342 MW of PV installations, 292 MW grid connected [Sei 2009]. California, New Jersey and Colorado account for more than 75% of the US grid-connected PV market. In 2008 the cumulative installed capacity was around 1.15 GW (768 MW grid connected). Production grew by 53% to 414 MW, mainly driven by the production increase of thin-film manufacturers United Solar (a-Si) and First Solar (CdTe). The US market share in the thin-film market is around 28% and much higher than the overall market share of 6%.

There is no single market for PV in the United States, but a conglomeration of regional markets and special applications for which PV offers the most cost-effective solution. In 2005 the cumulative installed capacity of grid-connected PV systems surpassed that of off-grid systems. Since 2002 the grid-connected market has been growing much faster, thanks to a wide range of “buy-down” programmes, sponsored either by States or utilities.

First Solar is continuing to expand its CdTe thin-film production capacity and plans to have 1.1 GW fully operational by the end of 2009 and more than 1.3 GW in 2011 [Fir 2009]. However, most of the production capacity is placed outside the US (790 MW Malaysia, 198 MW Germany, >100 MW France). United Solar has decided to expand its production capacity to 300 MW by 2010 and 1 GW in 2012 [Ecd 2008]. After the acquisition of the manufacturing assets of Shell Solar in 2006, SolarWorld AG acquired the Komatsu silicon wafer production facility in Hillsboro (OR) in 2007 and started to convert it into a wafer and solar cell manufacturing plant with up to 500 MW capacity. The new Hillsboro facility came on line in the autumn 2008 and ramp up is foreseen for 2009. Evergreen Solar is ramping up production as well and announced that they have secured enough silicon to increase production to 850 MW in 2012 [Eve 2008].

After years of political deadlock and negotiations concerning the support of renewable energies in the USA, things started to move in 2005. The main breakthrough was reached, when the 2005 Energy Bill was passed by the Senate on 29 July 2005 and signed by President Bush on 8 August 2005. The Bill’s main support mechanisms are:

- Increase of the permanent 10% business energy credit for solar to 30% for two years. Eligible technologies include Photovoltaics, solar water heaters, concentrating solar power, and solar hybrid lighting. The credit reverts back to the permanent 10% level after two years.

- Establish a 30% residential energy credit for solar for two years (until the end of 2008). For residential systems, the tax credit is capped at $ 2,000.
The second milestone was the final approval of the Californian “Million Solar Roofs Plan” or Senate Bill 1 (SB1), by the Californian Senate on 14 August 2006, and the signature by Governor Schwarzenegger on 21 August 2006. The Governor’s Office expects that the plan will lead to one million solar roofs, with at least 3 GW installed Photovoltaic electricity generating capacity in 2018.

Already in January 2006, the California Public Utilities Commission (CPUC) put the major piece of the plan into effect when it created the 10-year, $2.9 billion (€2.32 billion) “California Solar Initiative” to offer rebates on solar Photovoltaic systems. However, because the CPUC only has authority over investor-owned utilities, the rebates were funded by the customers of those utilities and only available to those customers. SB 1 expanded the programme to municipal utilities such as the Sacramento Municipal Utility District and the Los Angeles Department of Power and Water and allows the total cost of the programme to increase to as much as $3.35 billion (€2.39 billion). It also increases the cap on the number of utility customers that can sell their excess solar power generation back to the utility. That number was previously capped at 0.5% of the utility’s customers, but is now capped at 2.5% of the customers. Starting in 2011, SB 1 requires developments of more than 50 new single-family homes to offer solar energy systems as an option. It is believed that these Bills, together with other initiatives by individual States, will increase the demand for Photovoltaic solar systems in the USA by large.

On 23 September 2008, after more than a year of political debate the US Senate finally voted to extend the tax credits for solar and other renewable energies. On 3 October 2008, Congress approved and the President signed into law the “Energy Improvement and Extension Act of 2008” as part of H.R. 1424, the “Emergency Economic Stabilization Act of 2008”.

On 17 February 2009 President Obama signed the American Recovery and Reinvestment Act (ARRA) into law. The main solar provisions that are included in this bill are:

- The creation of a Department of Treasury (DOT) Grant Programme.
- Improvement to the investment tax credit by eliminating ITC penalties for subsidised energy financing.
- A new DOE Loan Guarantee Programme.
- Create tax incentives for manufacturing by offering accelerated depreciation and a 30% refundable tax credit for the purchase of manufacturing equipment used to produce solar material and components for all solar technologies.

Clean Renewable Energy Bonds (CREBs) were created under the Energy Tax Incentives Act of 2005\(^1\), for funding State, local, tribal, public utility and electric cooperative projects. The Energy Improvement and Extension Act of 2008 extended the CREB programme and changed some programme rules. The American Recovery and Reinvestment Act of 2009 expanded funding to $2.4 billion (€1.7 billion) of new allocations. Of this amount, $800 million (€571.4 million) is

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\( ^1 \) added Section 54 to the Internal Revenue Code
available for state, local, and tribal Governments; $ 800 million (€ 571.4 million) for public power providers; and $ 800 million (€ 571.4 million) for electric cooperatives (co-ops). Approved projects receive very low interest financing, some as low as 0.75 percent. Prior to new funds made available in ARRA, CREBs funded a total of 573 solar projects, more than half of the total 922 projects covered by $ 1.2 billion (€ 857.1 million) distributed in the first two rounds of funding authorised in 2005. The Energy Improvement and Extension Act of 2008 extended the CREB programme and changed some programme rules. The IRS accepted applications for new CREBs until 4 August 2009.

On 27 May 2009, President Obama announced to spend over $ 467 million (€ 333.6 million) from the ARRA to expand and accelerate the development, deployment, and use of geothermal and solar energy throughout the United States. The DOE will provide $ 117.6 million (€ 84 million) in Recovery Act funding to accelerate the widespread commercialisation of solar energy technologies across America. $ 51.5 million (€ 36.8 million) will go directly for Photovoltaic Technology Development and $ 40.5 million (€ 28.9 million) will be spent on Solar Energy Deployment, where projects will focus on non-technical barriers to solar energy deployment.

Despite the increase of grid-connected Photovoltaic system installations during the last years, with growth rates of around 40%, much still needs to be done to reach the targets of the “One Million Roofs” Initiative (Fig. 12).

Figure 13 shows the nation-wide figures for the average residential electricity prices 2009 (January to April) which increased in average by 7.5% from 10.49 ct/kWh to 11.28 ct/kWh. Taking these figures as a base, the US market for grid-connected systems can be classified into four categories where, according to local electricity costs net-metering and market incentives, a listed turn-key price for a PV system allows for competitive PV electricity production.

Although the majority of US States are in the category in which significant incentives are required, one quarter of the US population lives in the five best market States for PV. In those States, PV is cost-effective at an installed cost of $ 6/Wp (assuming long-term financing as in a mortgage). These five States also belong to those with the highest economic potentials.

The Energy Bill, the California SB 1 and other State Programmes are helping to accelerate the implementation of solar electricity. Whether or not the new support measures are sufficient and when they finally take effect to stimulate the necessary growth in US installations still has to be seen.

In September 2004, the US Photovoltaic Industry published their PV Roadmap through to 2030 and beyond “Our Solar Power Future” [Sei 2004]. The main goal of this Roadmap is: “Solar provides half of all new US electricity generation by 2025”. The Industry Association advocated effective policies sustained over time to increase solar power production and implementation in the US. Recommended actions were split into two sections:

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**Fig. 13:** Average residential electricity prices (US¢/kWh) for 2009 [Eia 2009].

- **Best markets:** (red) above 6 $/Wp; 10 States: California, Connecticut, Colorado, Delaware, Hawaii, Nevada, New Jersey, New York, Rhode Island, Texas
- **Cost effective markets:** (orange) between 4 $/Wp and 6 $/Wp; 9 States + DC Arizona, Florida, Maine, Massachusetts, Illinois, Ohio, Oregon, Utah, Vermont, Washington DC
- **Emerging markets:** (green) between 2.5 $/Wp and 4 $/Wp; 8 States Alaska, Georgia, Maryland, Minnesota, Montana, New Hampshire, New Mexico, Oklahoma
- **Significant incentives needed:** (blue) below 2.5 $/Wp; 23 States
Market Expansion

- Enact a residential and commercial tax credit that augments current state and federal support. The first 10 kW installed would receive a 50% tax credit capped at $3 per watt. Any amount above 10 kW would be eligible for a 30% tax credit capped at $2 per watt. Decreasing the caps by 5% per year will encourage a steady decline in prices and ease the transition to a market without tax credits.

- Modify the wind tax credit for solar so that it can be used together with the existing 10% investment tax credit.

- Establish uniform net metering and interconnection standards to give solar power owners simple, equitable access to the grid and fair compensation.

- Boost Federal Government procurement of solar power to $100 million per year to build public-sector markets for solar power.

- Support State public benefit charge programmes and other State initiatives to advance solar power and build strategic alliances with public and private organisations to expand solar markets.

Research and Development

- Increase R&D investment to $250 million per year by 2010.

- Strengthen investments in crystalline silicon, thin-film, and balance-of-systems components, as well as new system concepts that are critical to the industry now – reducing the gap between their current cost and performance and their technical potential.

- Support higher-risk, longer-term R&D for all system components that can leap-frog beyond today’s technology to new levels of performance and reduce installed system costs.

- Enhance funding for facilities and equipment at centres of excellence, universities, national labs (Sandia National Laboratories and the National Renewable Energy Laboratory) – as well as the Science and Technology Facility at NREL – to shorten by 50% the time between lab discoveries and industry use in manufacturing and products.

- Grow partnerships among industry, universities, and national laboratories to advance PV manufacturing and product technologies.
6.1 Incentives supporting PV

Due to the political situation in the US, there are no uniform implementation incentives for Photovoltaics. The “One Million Solar Roof” Initiative signed by President Clinton in 1997 lacks a dedicated budget and the Department of Energy (DoE) can only support measures for the removal of market barriers or the development of local promotion programmes. The goal of the Initiative is practical and market-driven: to facilitate the sale and installation of one million “solar roofs” by 2010. Eligible technologies include Photovoltaics (PV), solar water heating, transpired solar collectors, solar space heating and cooling and pool heating.

After years of political negotiations, the Federal 2005 Energy Bill went into effect. The main incentive is the increase of the permanent 10% business energy credit for solar to 30% for two years. In addition, it established a 30% residential energy credit for solar for two years. For residential systems, the tax credit is capped at $2,000. The extension of the tax credits until 2016 was finally approved by the U.S. Senate in September 2008 and signed into law on 3 October 2008.

The Californian SB 1 went into force on 8 August 2006 and the California Public Utilities Commission (PUC) adopted performance-based incentives for the California Solar Initiative on 24 August 2006. Since 1 January 2007, the PUC offers performance-based incentives for solar energy systems greater than 100 kWp in size, installed in businesses and other large facilities. For systems smaller than 100 kWp, incentives for residential and small businesses will be based on each system’s estimated future performance. Both mechanisms reward the selection and proper installation of high quality solar systems. This decision implements the first phase of the California Solar Initiative, which was adopted by the PUC in January 2006. The goal of the Solar Initiative is to increase the amount of installed solar capacity in California by 3,000 MW by 2017.

From 1 January 2007, residential and small commercial systems receive incentives of $2.50 per watt and will be eligible for additional federal tax credits. Government and non-profit organisations will receive $3.25 per watt (€2.32) to compensate for their lack of access to the federal tax credit. For systems larger than 100 kWp, incentive payments over the first five years of operation will be 0.39 $/kWh (0.279 €/kWh) of output for taxable entities and 0.50 $/kWh (0.357 €/kWh) of output for Government/non-profit organisations.

Many State and Federal policies and programmes have been adopted to encourage the development of markets for PV and other renewable technologies. These consist of direct legislative mandates (such as renewable content requirements) and financial incentives (such as tax credits). Financial incentives typically involve appropriations or other public funding, whereas direct mandates typically do not. In both cases, these programmes provide important market development support for PV. The types of incentives are described below. Amongst them, investment rebates, loans and grants are the most commonly used – at least 39 States in all regions of the country, have such programmes in place. Most common mechanisms are:

- personal tax exemptions
  (Federal Government, 21 States + Puerto Rico)

- corporate tax exemptions
  (Federal Government, 24 States + Puerto Rico)

- sales tax exemptions for renewable investments
  (27 States + Puerto Rico)

- property tax exemptions
  (35 States + Puerto Rico)

- buy-down programmes
  (19 States + District of Columbia, Virgin Islands, 234 utilities, 8 local)

- loan programmes and grants
  (Federal Gov., 40 States + Virgin Islands; 69 utilities, 17 local, 7 private)

- industry support and production incentives
  (Federal Government, 24 States + Puerto Rico, 33 Utilities, 9 private)

One of the most comprehensive databases about the different support schemes in the US is maintained by the Solar Centre of the State University of North Carolina. The Database of State Incentives for Renewable Energy (DSIRE) is a comprehensive source of information on State, local, utility, and selected federal incentives that promote renewable energy [Dsi 2009]. All different support schemes are described there and it is highly recommended to visit the DSIRE web-site http://www.dsireusa.org/ and the corresponding interactive tables and maps for more details.

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13DOE has defined a financial incentive as one that: (1) transfers economic resources by the Government to the buyer or seller of goods or a service that has the effect of reducing the price paid or increasing the price received; (2) reduces the cost of producing the goods or service; and/or (3) creates or expands a market for producers [Gie 2000].
Table 3: Financial Incentives for Renewable Energy [DSIRE]

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<th>Personal Tax</th>
<th>Corporate Tax</th>
<th>Sales Tax</th>
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<th>Loans</th>
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**TOTALS**: 22 44 67 43 3 11 5 55 88 36 8
A study by B.J. Rabe for the Pew Centre on Global Climate Change looks into the expanding role of US State Renewable Portfolio Standards [Rab 2006]. One of the key messages is:

States are compelled to enact or expand RPSs for multiple reasons, and greenhouse gas emissions may or may not be central factors in prompting adoption. Instead, States consistently anticipate significant economic development benefits from promoting renewables, particularly given the promise of developing home-grown energy sources that could lead to instate job creation. In turn, States are also attracted to RPSs by the prospect of greater reliability of electricity supply in coming decades and the prospect of reducing conventional air pollutants through a shift toward expanded use of renewables.

In August 2009, 29 States, the District of Columbia and Guam had Renewable Portfolio Standards, five additional States have State Goals and in Florida one utility has agreed on a RPS (Fig. 14). In 14 States and the District of Columbia the RPS include minimum solar or distributed generation (DG) provisions (Fig. 15).

Another very important measure for Photovoltaics is the grid access. In August 2009, 42 US States, Washington DC, Guam, Puerto Rico the Virgin Islands and American Samoa had implemented a net metering policy (Fig. 16). In Idaho, South Carolina and Texas some utilities have agreed on voluntary net metering.

The Union of Concerned Scientists predicts that State RPS and Renewable Energy Funds could lead to the development of 76,750 MW of new renewable production capacity by 2025. This would be an increase of more than 570% compared to the total US RE capacity in 1997 (excluding hydro) [Uni 2009]. The commitment to increase renewable energy use at the State level will have a significant impact on reducing CO₂ emissions. By 2025, these State RPSs will reduce total annual CO₂ emissions by more than 183 million tons CO₂ which is the equivalent of taking 30 million cars off the road.

The benefits at State level do not only include the significant reduction of greenhouse gas emissions, but they are also an effective means to diversify energy supply sources, increase energy security and create local jobs and economic benefits. The later reasons are probably behind the fact that a number of States have recently revisited and significantly increased or accelerated their annual requirements.

Most of these capacities will be wind, but Photovoltaic electricity is seen more and more as an option as well. Therefore, it is interesting that 10 other States have followed the Colorado RPS with a specific target for solar electricity. In addition, a number of States have provisions in their RPS which counts electricity from PV systems with a higher multiplier. The RPS laws in California and New York create the two largest markets for new renewable energy growth in the short term.

In December 2007, Ken Zweibel, James Mason and Vasilis Fthenakis published their vision “A Solar Grand Plan” for the U.S. in Scientific America [Zwe 2007]. The paper describes how Photovoltaic technology could provide almost 3,000 GW of power by 2050. According to the authors, solar must become competitive at the mass-production level in a first phase from now until 2020. In order realize this, about 84 GW of Photovoltaics and concentrated solar power plants would have to be built by 2020. In parallel, it would be necessary to lay the foundation of the necessary High Voltage Direct Current (HVDC) transmission system.

The realisation of such a plan would drastically change the market situation, as well as the production and technology base in the U.S.

Legend for table 3 and 4, pages 56/57:

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http://www.dsireusa.org

* In addition, some private renewable energy credit (REC) marketers provide production-based incentives to renewable energy project owners.

For more info see:

**Fig. 14:** States with Renewable Portfolio Standards in the US (August 2009); Figure © DSIRE [Dsi 2009].

- **Renewable Portfolio Standards**
  - States with RPS Policies with Solar/DG Provisions (August 2009)
  - Figure © DSIRE [Dsi 2009]

- **States with Renewable Portfolio Standards**
  - WA: 15% by 2020
  - MT: 15% by 2015
  - MN: 25% by 2025
  - VT: (1) RE needs any increase in retail sales by 2012; (2) 20% RE & CHP by 2017
  - NH: 23.4% by 2025
  - MA: 15% by 2020
  - RI: 16% by 2020
  - CT: 23% by 2020
  - OR: 25% by 2023 (large utilities)
  - ID: 10% by 2015
  - UT: 25% by 2025
  - NV: 25% by 2025
  - CA: 20% by 2015
  - NV: 25% by 2025
  - CO: 28% by 2020 (RRP
  - WA: double credit for non-wind (Non-wind goal: 500 MW)
  - CA: 20% by 2015
  - TX: 5,880 MW by 2013
  - WA: 15% by 2020
  - NH: 0.3% solar-electric by 2014
  - MA: TBD

- **29 states & DC have an RPS**

- **5 states have goals**

- **Fig. 15:** US States with RPS Policies with Solar/DG Provisions (August 2009); Figure © DSIRE [Dsi 2009].

- **RPS Policies with Solar/ DG Provisions**

- **States with RPS Policies with Solar/DG Provisions (August 2009)**
  - WA: double credit for DG
  - NV: 1.5% solar by 2025
  - CO: 0.8% solar-electric by 2020
  - MO: 0.3% solar-electric by 2021
  - NH: 0.3% solar-electric by 2014
  - MA: TBD
  - UT: 2.4 multiplier for solar
  - AZ: 4.5% DG by 2025
  - NM: 4% solar-electric by 2020
  - NC: 0.2% solar by 2018
  - NY: 8.1312% customer-sited by 2013
  - NJ: 2.12% solar-electric by 2021
  - PA: 0.5% solar PV by 2020
  - DE: 2.005% solar PV by 2019; triple credit for PV
  - MD: 0.4% solar by 2020; 1.1 multiplier for solar
  - TX: double credit for non-wind (Non-wind goal: 500 MW)
  - DC: 20% by 2020

- **14 states & DC have an RPS with solar/DG provisions**

- **Note:** RI requires 3 MW of solar by 2014, but this not part of the state’s RPS policy.
Fig. 16: US States with Net-metering in the US (August 2009) and upper limits; Figure © DSIRE [Dsi 2009].

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</tr>
<tr>
<td>NC</td>
<td>1,000*</td>
</tr>
<tr>
<td>VA</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: Numbers indicate system capacity limit in kW. Some state limits vary by customer type, technology and/or system application. Other limits might also apply.
6.2 Solar Energy Technologies Programme

The aim of the US Solar Energy Technologies Programme (SETP or Solar Programme) is to develop cost-competitive solar energy systems for America. The current Multiannual work-programme runs from 2008 to 2012 [DOE 2008]. More than $170 million (€121.4 million) are spent each year for research and development on the two solar electric technologies which are considered to have the greatest potential to reach cost competitiveness by 2015: photovoltaics and concentrating solar power. The programme names as the greatest R&D challenges the reduction of costs, improvement of system performance, and the search for new ways to generate and store energy captured from the sun.

The Solar Programme also aims to ensure that the new technologies are accepted in the marketplace. Work is done to remove many non-technical market barriers, such as updating codes and standards that aren’t applicable to new technologies, improving interconnection agreements among utilities and consumers, and analyzing utility value capacity credits for utilities. Such activities should help consumers, businesses, and utilities to make more informed decisions when considering renewable energy, and they also facilitate the purchase of solar energy.

The Solar Programme conducts its key activities through four sub-programmes:

- Photovoltaics
- Concentrated Solar Power
- Systems Integration
- Market Transformation.

The 2008-2012 timeframe emphasizes the following areas:

1. Fully incorporating concentrating solar power (CSP) efforts into the Solar America Initiative (SAI).
2. Improving storage technologies for both CSP and PV technologies.
3. Better integrating solar technologies into the electric grid, in both distributed and centralised generation applications.
4. Eliminating city and state level technical and regulatory barriers to solar technology deployment.
5. Improving the ability of DOE and its laboratories and partners to quickly and effectively transfer R&D concepts from basic to applied science and then to the marketplace.
6. Exploring and developing the next generation of PV technologies that will reach consumers beyond the SAI timeframe (post-2015).
7. Assisting U.S. industry in regaining its leadership role in the global solar marketplace.
8. Promoting increased understanding of environmental and organisational safety across all Solar Programme activities by all participants.

The Solar Programme goals support the DOE 2006 Strategic Plan [DOE 2006], which identified five strategic themes amongst them energy security, which is a key driver of the Solar Programme activities supported by the DOE. In addition, the Programme supports the research and development provisions and broad energy goals outlined in the National Energy Policy Act 2005 (EPAct 2005) and the Energy Independence and Security Act (EISA). In both acts, Congress expressed strong support for decreasing dependence on foreign energy sources and decreasing the cost of renewable energy generation and delivery. Support from Congress and state Governments and the availability of financial incentives are important for achieving the Solar Programme goals.

The Solar Programme lists economic targets for PV (Table 5), which were determined by an analysis of key markets. They were set based on assessments of the Levelised Costs of Energy (LCOE) for solar technologies to be competitive in these markets.

According to the Solar Programme, the residential and commercial price targets are based on current retail electricity prices and take into consideration the rather optimistic projection of the Energy Information Administration (EIA) that electricity prices will remain fairly constant (in real terms) through 2025. With these assumptions, the Programme predicts that meeting the solar market cost goals will result in 5-10 GW of PV installed by 2015 and 70-100 GW by 2030 in the U.S.
Ten Photovoltaic technology roadmaps were developed in 2007 by staff at NREL, Sandia National Laboratories, DOE, and experts from universities and private industry [DOE 2008a]. This work was done, in part, to support activities within the Solar America Initiative. These technology roadmaps summarise the current status and future goals for the specific technologies. The Roadmaps for Intermediate-Band PV, Multiple-Exciton-Generation PV and Nano-Architecture PV are still in a draft stage.

6.2.1 Solar Technology Research Plan

The U.S. strategy for overcoming the challenges and barriers to massive manufacturing, sales, and installation of PV technology is to achieve challenging targets throughout the development pipeline. Multiple technologies are being pursued that are at differing stages of maturity. With an effective combination of the talents in industry, university, and national laboratories, the needed cost, performance and reliability goals should be achieved. Specific PV R&D efforts toward achieving these goals include:

1. PV Systems & Module Development
2. PV Materials & Cell Technologies
3. Testing & Evaluation
4. Grid / Building Integration

The PV sub-programme’s R&D activities are divided into the following three categories:

6.2.1.1 New Devices and Processes

The emphasis of the Solar Energy Technologies Programme photovoltaic research in new devices is to develop novel PV devices and processes with potentially significant performance and/or cost advantages.

The proposed research targets the following photovoltaic areas:

- Design, development, and preliminary degradation testing of lab-scale device prototypes
- Completion of process demonstrations in lab-scale evaluations
- Preliminary science investigations or literature review without component or system prototype development
- Assessment of initial technical and market product or process technology concepts using laboratory investigations
- Physics-based modelling
- Parametric estimation
- Other relevant analytical methods.
This research focuses on two areas:

1. **Next Generation PV**
   - In April 2007, DOE made a call for projects on “Next Generation Photovoltaic Devices and Processes” to develop innovative Photovoltaic cells and/or processes by 2015. Potential areas of interest included, but were not limited to, the following:
     - Photovoltaic devices-organic, crystalline, non-single-crystal devices, photoelectrochemical, advanced multi-junction, low-dimensional structures, optimised interfaces, transport properties, and cross-cutting issues
     - Hybrid PV concepts-hydrogen generation, powered electrochromics, and storage
     - Manufacturing-low-cost techniques, environmental/recycling issues, and novel manufacturing processes.
   - The PV device and manufacturing process research activities in this area are expected to produce prototype PV cells and/or processes by 2015, with full commercialisation by 2020-2030. Next Generation PV projects started at the end of 2007.

2. **Photovoltaic Technology Pre-Incubator**
   - The new project is aimed to help small solar businesses transition from concept verification of a solar PV technology to the development of a commercially viable PV prototype by 2012. The goals of the project include promoting grid parity for PV technologies, transitioning innovative PV technologies into the prototype stage, and developing prototype PV concepts with manufacturing costs of less than $1/watt.
   - The PV Technology Pre-Incubator project complements the PV Technology Incubator project, which was launched in 2007. While both support small businesses, each focuses on a different phase of the research and development (R&D) process. The Pre-Incubator project focuses on moving ideas from concept verification to commercially viable prototype, and the PV Incubator project targets accelerating prototype and pre-commercial technologies toward pilot and full-scale production.
   - The PV Technology Pre-Incubator targets the R&D advances needed to overcome barriers to creating an innovative and viable PV device or module prototype that is suitable for manufacturing scaleup. Technology neutral, this project encompasses innovative PV cell and module technologies suitable for residential rooftop, commercial rooftop, and utility markets.

### 6.2.1.2 Prototype Components and Systems
The Solar America Initiative’s research in component and system prototypes emphasizes development of prototype components and systems produced at pilot-scale. The demonstration of cost, reliability, or performance advantages is required.

The proposed research will target the following:

- Development of component prototype design with full functionality and complete “look and feel” of commercial products
- Accelerated and qualifications testing to improve component design and gain early insight into reliability issues
- Complete proof of concept for all new manufacturing processes in pilot-scale operations
- Lab testing to provide data for systems integration and optimisation
- Evaluate component costing based on pilot production processes.

The financing tool for this task is called Photovoltaic Incubator funding. The funding structure for this solicitation is intended to be flexible and cyclical. The performance period of each project is 18 months, with the possibility of project termination after a DOE stage gate review at month nine. The projects have been structured so that companies will receive their funding from DOE only upon successful delivery of pre-specified samples of new hardware. This approach will allow early-stage companies to focus on demonstration of technology, while assuring that taxpayers get the best value for their investment in these projects.

In September 2008, the DOE announced the second round of winners for its Photovoltaic (PV) Incubator funding opportunity. The projects focus on developing prototype PV components and systems and barriers to entry for 2010 commercialisation. The result of the first round was announced in June 2007.

The PV Incubator awards target research and development of PV systems and component prototypes with full functionality, produced in pilot-scale operations. Prototype technologies are expected to have already completed proof-of-concept for new manufacturing processes, either through contractor equipment, the NREL Process Development and Integration Laboratory facilities, or other appropriate facilities. Goals of these projects are:
Explore the commercial potential of new manufacturing processes and products

Foster innovation and growth in the domestic PV industry

Establish an efficient and cyclic funding opportunity

Expand and diversify domestic “market-ready” PV technologies

6.2.1.3 Systems Development and Manufacturing

These R&D activities are intended for collaboration and partnership among industry and university researchers on components and systems that are ready for mass production and capable of delivering electricity at Solar America Initiative target costs.

This research is divided into two areas:

(1) Technology Pathway Partnerships – Activities focused on research and development (R&D) of concentrating solar power (CSP) and Photovoltaic (PV) component and system design that is ready for mass production and capable of delivering energy at target costs.

The teams selected for the Technology Pathway Partnerships include companies, laboratories, universities, and non-profit organisations to accelerate the drive toward commercialization of U.S.-produced Photovoltaic (PV) systems. These partnerships comprise more than 50 companies, 14 universities, 3 non-profit organisations, and 2 national laboratories. The current project phase focuses on projects for the development, testing, demonstration, validation, and interconnection of new PV components, systems, and manufacturing equipment. The current goals are:

- Bring better products to market and enable new applications
- Foster the development of the domestic PV industry
- Impact the U.S. energy economy with results

(2) University Process and Product Development Support – Targeted materials science and process engineering research by universities in support of industry-led teams who are developing new CSP and PV systems for commercialisation by 2010 to 2015.

This project part focuses on University-led system development and manufacturing research that emphasises direct, near-term improvements in PV products and development processes by universities in support of the Solar America Initiative goals. The goals are to leverage university understanding and experience improving PV products and process development.

(3) Photovoltaic Supply Chain and Cross-Cutting Technologies: This project identifies and accelerates the development of unique PV products or processes that will impact the solar industry. The project supports the overall goals of the U.S. Department of Energy (DOE) Solar Energy Technologies Programme (SETP or Solar Programme).

Non-solar companies have many technologies and practices that are beneficial to the PV industry. These capabilities can be used in PV-specific manufacturing methods and products. Examples of such high-impact technologies include processing steps to improve throughput, yield, or diagnostics; material solutions to improve reliability or enhance optical, thermal, or electrical performance; or system components that streamline installation. The cost reduction as a result of these improvements might be small in terms of a single product or processing step, however, the overall impact of these ideas become significant when implemented across the PV industry.

Funded projects range from automated assembly to semiconductor fabrication, and target manufacturing and product cost reduction with the potential to have an impact within 2 to 6 years on a substantial segment of the PV industry.

In addition, the Solar America Initiative’s Market Transformation activities address barriers to commercialisation of solar energy technologies.

6.3 Very High Efficiency Solar Cell Programme

In 2005 the US Defence Advanced Research Projects Agency initiated the Very High Efficiency Solar Cell (VHESC) Programme to develop 50% efficient solar cells over the next years. The aim of the Programme is to reduce the average load of 20 pounds (ca 9 kg) that an average soldier has to carry to power the portable technology gadgets used.

The initial phase which started in November 2005 was co-ordinated by the University of Delaware. Partners in this phase included BP Solar, Blue Square Energy, Energy Focus, Emcore and SAIC. Key research contributors included the University of Delaware, National Renewable Energy Laboratory, Georgia Institute of Technology, Purdue University,
During the initial phase the co-design of optics and solar cell architectures enabling ultra-high efficiency and low cost manufacture was investigated. The relevant topics were:

- **Lateral solar cell architecture** – this expands material choice (no lattice/current mismatch), increases performance

- **Substrate is high performance, low-cost silicon solar cell independently-contacted vertical solar cell architecture**
  - expands material choice
  - monolithic structure with low materials and fabrication costs
  - no tunnel junctions

- **Low cost multijunction solar cell**
  - New structures based on existing high efficiency materials
  - Parallel paths and materials for high, mid and low energy photons

- **High performance substrate, low-cost silicon solar cell**

- **Quantum dot solar cells**
  - optimised solar cell structures selective energy contacts
  - closely spaced QD arrays

In July 2007 DARPA announced the start of the second phase of the programme by funding the newly formed DuPont-University of Delaware VHESC Consortium to transition the lab-scale work to an engineering and manufacturing prototype model. For this purpose, DARPA awarded the consortium $12.2 million as part of a three-year, multi-phase programme that could total up to $100 million. DuPont is managing the consortium of proposed companies and scientific institutions dedicated to the optimisation of the VHESC solar cells for efficiency and cost.

### 6.4 The US PV-Industry Roadmap

To meet the challenge of the expanding PV markets the US-based PV industry has developed a PV Roadmap as a guide for building their industry in 2001 and updated it in 2004 [Sol 2001, Sei 2004]. In 2001 the main issues were concerned with ensuring US technology ownership and implementing a sound commercialisation strategy that should yield significant benefits at minimal cost. To do so they call for “reasonable and consistent co-investment by our industry and Government in research and technology development”. Despite the high investments needed, the environmental and direct economic benefits, together with the additional energy security, will by far exceed the investments.

In the 2004 update the US Industry states that their original analysis on cost reduction and market development was right, but that the necessary investments to achieve the goals were not made in the US but in Japan and Germany. It is highlighted that California is one of the shining stars in the US regarding PV implementation. The success there cannot substitute a national commitment to develop the markets. The conclusion drawn is: “Effective policies sustained over time increase solar power production, make markets grow dramatically, improve technology and reduce costs.”

In the 2004 update, the industry showed two scenarios. The first one, Business as Usual and the more ambiguous “Roadmap” scenario, where the target figures are increased compared to 2001. Under the Roadmap scenario, PV should provide half of all new US electricity generation by 2025 and produce approximately 7% of the national electricity compared to 1% in the BAU case. Within the next 25 years the PV Industry expects to employ more than 260,000 people (59,000 in case of BAU) in the US. To reach these goals the PV Industry argues that market leadership has to be reclaimed and technology ownership has to be maintained. The following measures are supposed to do so, by the American PV Industry in their Roadmap.

#### Reclaim Market Leadership

- **Create Incentives for Market Leadership** – Implement tax credits for residential and commercial installations that augment current state and federal support. The first 10 kWp installed should receive a 50% tax credit capped at $3 per watt. Any amount above 10 kWp would be eligible for a 30% tax credit capped at $2 per watt. Decreasing the caps by 5% per year will encourage a steady decline in prices and ease the transition to a market without tax credits. The wind production tax credit for solar power should also be expanded in
a manner that allows it to be used in combination with the existing 10% tax credit for businesses that install solar power equipment.

■ Establish Uniform Net Metering and Interconnection Standards to give solar power owners everywhere the right to simple, equitable access to the grid and fair compensation for the value of the solar power they supply.

■ Boost Government Procurement of solar power to $100 million per year by allowing 20-year Power Purchase Agreements and by appropriating funds for Federal Agencies to install solar energy. Leaders should dedicate appropriations for green solar power purchases and direct agencies to use solar power equipment where it can increase energy security and emergency preparedness for the largest electricity consumers in the United States – Federal and State Governments.

■ Support and Reinforce State and Local Efforts to Advance Solar Power by designing federal incentives to lever existing state solar support and encourage other States to adopt solar policies that open new markets, increase sales volume, and help consumers, utilities, and communities benefit from solar electricity.

■ Increase the DOE Solar R&D Budget to $250 Million Per Year by 2010 to leverage our R&D excellence and thus build solar markets by balanced programmes on current crystalline silicon and thin-films, manufacturing, reliability, and next-generation PV technologies. Solar power research has helped reduce their costs by nearly 50% in a decade and is essential to make it broadly competitive in the next decade. DOE and its national laboratories should validate solar system performance to reassure financial institutions and help reduce the cost of capital for the solar industry. The programme should lead in higher-risk research, advancing potentially disruptive (“leapfrog”) technologies and processes.

Maintain Technology Ownership

The foundation of successful technology is excellent research and development. The US industry recognises that to reduce solar power system costs, increase the energy delivered from its components and systems, and enhance its manufacturing efficiency (i.e., throughput and yield), the following investments in balanced federal R&D are essential:

■ Foster technologies that exist now or are near commercialisation, which are critical to our current US industry – This includes crystalline silicon and thin-films, as well as balance-of-systems components. This focus will decrease the gaps between where these manufactured technologies are now and what they can realistically achieve, helping to ensure that we meet the Roadmap’s technical goals over the next 10 years.

■ Position the United States to own the coming generations of solar power technologies – Investing in R&D for higher-risk, longer-term technology will provide options to leapfrog beyond today’s technology to new levels of performance and reduced costs. This R&D includes developing new materials that push current technologies to the next performance level, discovering and demonstrating new devices with ultra-high efficiencies (e.g., nanotechnology approaches, multiple-junction and layered devices), and developing devices with ultra-low costs (e.g., organic or plastic solar cells, ultra-thin-films). Investments must also stimulate the next generation of fully integrated solar energy systems. This includes modules and balance-of-systems components, including novel and “smart” electronics, optics, integration, architecture-based energy, storage, hydrogen production, and advanced power electronics.

■ Enhance support for existing centres of excellence, national labs and NREL’s Science and Technology Facility – This is critical to improve crystalline silicon and thin-films. These centres help to shorten the time between laboratory discovery and industry use by at least 50%, significantly accelerating the transfer of innovation to the market-place. They also provide rapid response to overcome manufacturing issues and barriers identified by industry.

■ Continue to develop programmes and partnerships among industry, universities, and national laboratories – Partnerships in PV manufacturing R&D and thin-film development have produced unprecedented cost sharing, research collaboration, and publishing a model for research that should be expanded and strengthened. The previous roadmap identified the doubling of the Federal R&D investment as a critical strategy for success. This did not occur, and global competition has advanced and threatens to knock the US out of research leadership. To reverse this trend, the United States are called to gradually increase its annual R&D investment to $250 million by 2010. This moderate investment will accelerate the current US industry’s technology strength in capturing near-term markets and will ensure that the United States owns and manufactures the solar products that will serve future generations.
Compared to the 2001 scenario, the new update emphasizes the importance of a strong home market in order to develop the local industry in the long term. This is in contrast to the earlier assumption that US PV-Industry Roadmap could depend on 70% export rate of their annual production. A strong home market like in Japan, where it accelerated the expansion of production capacities, is still missing in the United States. This might be one of the reasons why it lost its market leader position, held for many years, and is now at fourth place behind Japan, Europe and China.

6.5 Solar Companies

In the following chapter most of the current cell manufacturers in the U.S. are described briefly. This listing does not claim to be complete, especially due to the fact that for some companies, information or data were very fragmented. Data were collected from the companies’ web-sites. A lot of start-up companies are missing due to sparse and sometimes contradictory information.

6.5.1 BP Solar
BP Solar has its headquarters in Linthicum, MD, and has various factories world-wide. BP Solar moved from third place in 2004, with 85 MW to number 16 in 2008 with 156 MW. BP Solar had 4 solar cell plants located in Madrid, Spain (Tres Cantos: 27.7 MW, c-Si Saturn solar cells), Sydney-Homebush Bay, Australia (28.8 MW, mc-Si and c-Si Saturn solar cells), Bangalore (joint venture with Tata), India (80 MW, mc-Si), and Frederick, Maryland (19.8 MW mc-Si).

BP Solar operates joint ventures in India, Malaysia, Saudi Arabia, South Africa, Thailand and Indonesia. According to the company, production capacity in 2007 was 228 MW with an additional 700 MW under construction. The production capacity at the Homebush Bay Plant, Australia was 50 MW, but the plant was closed at the end of March 2009.

In 2007, BP announced the expansion of production capacities. At that time it was planned to increase capacity at the Frederick Plant to 150 MW, but with space for further enlargements of the manufacturing capacity to 400+ MW in its casting, sizing, and wafering processes [Bps 2007]. Construction was slated for completion by the end of 2009.

In 2008 Tata BP Solar announced that they had secured funding for their 128 MW capacity expansion, which is a crucial step to realise the expansion to 300 MW [Tat 2008].

In March 2009 BP announced to refocus its manufacturing activities, and as a result module assembly in Frederick will be phased out and its cell manufacturing and module assembly facilities in Spain will close [Bps 2009]. Silicon casting, wafering, sizing and solar cell production in Frederick will continue. This announcement is in line with the supply deals BP Solar signed in 2008 with a number of wafer suppliers and cell manufacturers to supplement its own manufacturing capacity.

6.5.2 Evergreen Solar
Evergreen Solar, founded in 1994, develops, manufactures and sells solar power products, primarily solar panels. The company serves three markets: wireless power, rural
electrification and grid-connected applications. The company uses its String Ribbon wafer production to produce distinctive products, to reduce manufacturing costs through lower materials use and streamlined processes, and to manufacture internationally for global market penetration. Production in 2008 was 26.5 MW [Pvn 2009]. According to the company, the first 80 MW phase of their new facility in Devens was opened in June 2008, with the second 80 MW planned to become operational in 2009. The company has announced that it has secured enough silicon feedstock to grow to 850 MW production in 2012.

On 30 July 2009 Evergreen announced the signing of a manufacturing agreement with Jiawei Solar, PRC [Eve 2009]. Under the agreement, Evergreen will manufacture String Ribbon wafers in at Jiawei’s facility in China and Jiawei will then use the wafers to manufacture Evergreen Solar-branded modules. The initial capacity of the factory will be 100 MW and should be fully operational in 2010. A further expansion to 500 MW is intended to be realised by 2012.

Evergreen Solar has a joint venture Sovello with Q-cells, Germany, and Renewable Energy Corporation ASA (REC), Norway in Thalheim, Germany, which is located approximately 80 miles from Berlin. In June 2007 the second production line started operation, bringing the total capacity of EverQ to 100 MW. Production in 2008 was 94 MW. According to the company, production capacity in 2009 will reach 180 MW.

6.5.3 First Solar LLC.
First Solar LLC is one of the companies world-wide to produce CdTe-Thin-film modules. First Solar has developed a solar module product platform that is manufactured using a unique and proprietary Vapour Transport Deposition (VTD) process. The VTD process optimises the cost and production throughput of thin-film PV modules. The process deposits semiconductor material while the glass remains in motion, completing deposition of stable, non-soluble compound semiconductor materials.

First Solar is continuing to expand its CdTe thin-film production capacity massively. The latest announcement was made in July 2009 to build a new factory in a joint venture with EdF Nuovelles in France with at least 100 MW capacity [Fir 2009]. The company has currently four manufacturing plants in Perrysburg (U.S.A.), Frankfurt/Oder (Germany) and two in Kulim (Malaysia), which will have a combined capacity of 1.1 GW at the end of 2009. In 2008 the company produced 503 MW and currently sets the production cost benchmark with 0.86 $/Wp (0.62 €/Wp) in the second quarter of 2009.

6.5.4 Global Solar Energy Inc.
GSE is located in Tucson and was established in 1996. In 2006, German module manufacturer, SOLON AG, acquired a 19% stake in Global Solar Energy Inc. The remaining 81% are owned by a European venture capital investor. The company is producing thin-film Photovoltaic CIGS solar cells for use in solar products, as well as installing and managing large solar Photovoltaic systems. According to the company, the new 40 MW plant was opened in March 2008 and 35 MW plant in Germany opened in the autumn of 2008. With plans to expand production capacity by an additional 100 MW in 2009, GSE aims for 175 MW production capacity in 2010 [Gio 2008]. In 2008, 7 MW production was reported [Pvn 2009].

6.5.5 United Solar Systems
United Solar Systems Corp. is a subsidiary of Energy Conversion Devices, Inc. (ECD). The first 25 MW manufacturing facility of the flexible a-Si triple junction solar cell is located in Auburn Hills (MI) and was inaugurated in 2002. The plant is fully automated and allows simultaneous processing of six rolls of stainless steel, each 1 ½ miles long, during deposition of the a-Si layers.

According to the company, production capacity will expand to 320 MW by 2010 and 720 MW in 2011. In 2008 financing deals were closed which would allow an expansion to 1 GW in 2012 [Ecd 2008]. The current nameplate capacity in Auburn Hills is quoted with 58 MW and in Greenville, Michigan 120 MW. Additional expansion is planned in China where a joint venture with Tianjin Jinneng Investment Company (TJIC) will build a 30 MW module plant in Tianjin. Production in 2008 increased to 113 MW [Pvn 2009].

6.5.6 SunPower Corporation
SunPower was founded in 1988 by Richard Swanson and Robert Lorenzini to commercialise proprietary high-efficiency silicon solar cell technology. The company went public in November 2005. SunPower designs and manufactures high-performance silicon solar cells, based on an interdigitated rear-contact design for commercial use. The initial products, introduced in 1992, were high-concentration solar cells with an efficiency of 26%. SunPower also manufactures a 22% efficient solar cell called Pegasus that is designed for non-concentrating applications.

SunPower conducts its main R&D activity in Sunnyvale, California and has its cell manufacturing plant outside of Manil in the Philippines. Fab. № 1 has a nameplate capacity of 108 MW. Fab. № 2 was fully operational at the end of 2008 with a capacity of 306 MW. For 2009 a capacity increase to 574 MW is foreseen. According to their Annual Report 2008, the company started the construction of a 1 GW solar cell factory in Malaysia. Production in 2008 was quoted with 237 MW [Pvn 2009].
6.5.7 Additional Solar Cell Companies

■ Abound Solar, Inc. (formerly AVA Solar) was founded in 2007 to commercialise the manufacturing of cadmium telluride (CdTe) thin-film Photovoltaic modules. On 14 April 2009 the company announced the start of commercial production at their factory in Longmount (CO), which will have a capacity of 200 MW, if fully operational.

■ Ascent Solar Technologies Incorporated was established in 2005 to manufacture CIGS thin-film solar modules with a roll-to-roll process. According to the company, it is on track to commence full scale production on their 1.5 MW pilot line by the end of 2008. A 30 MW production line is planned to be completed in 2009 and for 2012 the company plans to increase production capacity to 110 MW.

■ DayStar Technologies was founded in 1997 and conducted an Initial Public Offering in February of 2004. Products are: LightFoil™ and TerraFoil™ thin-film solar cells based on CIGS. In addition, DayStar has its patented ConcentraTIR™ (Total Internal Reflection) PV module which has been designed to incorporate a variety of cell material components, including wafer-Si, Spheral Si, thin-film CIGS and a-Si.

■ EPV SOLAR Inc. (EPV) is a solar energy company that designs, develops, manufactures, and markets amorphous silicon thin-film photovoltaic solar modules. On 1 December 2008 the company announced that EPV SOLAR Germany GmbH started production at their 30 MW Senftenberg factory, increasing total capacity to 55 MW.

■ GE Energy acquired the US business assets of AstroPower in March 2004 for about $ 19 million [Gee 2004]. GE Energy (www.gepower.com) is one of the world’s leading suppliers of power generation and energy delivery technology based in Atlanta (GA). AstroPower began as a division of AstroSystems Inc., founded in 1983 as an outgrowth of semiconductor work initiated at the University of Delaware. In 1989, the company was incorporated in Delaware. The company went bankrupt in 2003 and sales dropped from 29.7 MW in 2002 to 17 MW in 2003 and GE Energy sales recovered to 22 MW in 2006. For 2008 no significant production was reported. In June 2008, GE Energy became the largest shareholder in the thin-film solar start-up company PrimeStar Solar.

■ Miasolé was formed in 2001 and produces flexible CIGS solar cells on a continuous, roll-to-roll production line. The company has installed two 20MW production lines in its Santa Clara facility. In July 2008 the company announced that NREL has measured their modules based on their flexible cells encapsulated in a glass/glass construction with more than 10% efficiency [Mia 2008].

■ Nanosolar was founded in 2001 and is based in Palo Alto. It is a privately held company with financial-backing of private-technology-investors. According to the company, Nanosolar developed nanotechnology and high-yield high-throughput process technology for a proven thin-film solar device technology based on CIGS. The company made headlines when it announced on 21 June 2006 that it has secured $ 100 million in funding and intends to build a 430 MW thin-film factory [Nan 2006].

■ Power Films Inc. was founded in 1988 to develop and manufacture thin-film silicon solar cells. The company announced in its 2008 first half year report that it continues to make progress with its strategic objective of achieving 10 MW production capacity by the end of 2009 and 24 MW of capacity by the end of 2010.

■ Signet Solar Inc. was incorporated in 2006. Since November 2008 Signet Solar is producing PV panels near Dresden, Germany, using a fully-integrated thin-film solar production line from Applied Materials. The company plans to expand capacity in Germany to 130 MW by 2011 and is also planning to establish manufacturing facilities in New Mexico USA (expected production by early 2011). Signet India was founded in 2007 and it is planned to start production there in 2010.

■ Solo Power Inc., founded in 2006, is a California-based manufacturer of thin-film solar photovoltaic cells and modules based on CIGS. In June 2009 the company received certification under ANSI/UL 1703 standard. According to the company, they started to ramp up their 20 MW facility in 2008.

■ Solyndra was founded in 2005 and produces PV modules using their proprietary cylindrical CIGS modules and thin-film technology. The company operates a state-of-the-art 300,000 square foot factory, which would allow production of up to 100 MW.

■ Suniva Inc. was founded in 2007 by Dr. Ajeet Rohatgi, Director of Georgia Tech’s University Center of Excellence for Photovoltaic Research and Education. On 4 November 2008 the company announced the start of production at their 32 MW factory in Norcross (GA). For 2009, an expansion to 96 MW is planned.
Xunlight Corporation is a technology spin-off from the University of Toledo (OH) to develop and manufacture flexible and lightweight thin-film silicon solar modules. On 22 June 2009 the company announced that it has successfully completed the installation of its first 25 MW roll-to-roll photovoltaic manufacturing equipment.

6.5.8 AE Polysilicon
AE Polysilicon was founded in 2006 to manufacture polysilicon for the solar industry. On 19 February 2008 the company broke ground on its production facility at its site at the Keystone Industrial Port Complex (KIPC) in Fairless Hills (PA). The initial 1,800 ton facility scheduled to start test production in late 2008 and commercial production in 2009.

6.5.9 Hemlock Semiconductor Corporation
Hemlock Semiconductor Corporation is based in Hemlock, Michigan. The corporation is a joint venture of Dow Corning Corporation (63.25 %) and two Japanese firms, Shin-Etsu Handotai Company, Ltd. (24.5 %) and Mitsubishi Materials Corporation (12.25 %). The company is the leading provider of polycrystalline silicon and other silicon-based products used in the semiconductor and solar industry.

In 2007 the company had an annual production capacity of 10,000 tons of polycrystalline silicon and production at the expanded Hemlock site (19,000 tons) started in June 2008. A further expansion at the Hemlock site as well as a new factory in Clarksville, Tennessee, was started in 2008 and should bring total production capacity to 34,000 tons in 2010.

6.5.10 Hoku Scientific, Inc.
Hoku Scientific is a material science company founded in 2001 and based in Kapolei, Hawaii. The company has three business units: Hoku Fuel Cells, Hoku Solar and Hoku Materials.

In September 2008 Hoku Materials announced that they had adjusted their planning for the polysilicon manufacturing plant located in Pocatello (ID) to 3,500 tons in order to meet customer demand [Hok 2008]. Reactor demonstration was planned for the first quarter of 2009 and the plant should become operational at full capacity in 2010. Due to the changed economic conditions, the timeline has been changed in June 2009.

6.5.11 MEMC Electronic Materials Inc.
MEMC Electronic Materials Inc. has its headquarters in St. Peters, Missouri. It started operations in 1959 and the company’s products are Semiconductor-grade Wafers, Granular Polysilicon, Ultra-high purity Silane, Trichlorosilane (TCS), Silicon Tetrafluoride (SiF4), Sodium Aluminum Tetra-
The political structure of the European Union, with 27 Member States is quite diverse and there is no unified approach towards renewable energies yet. However, during the European Council Meeting in Brussels on 8-9 March 2007, the Council endorsed a binding target of a 20% share of renewable energies in the overall EU energy consumption by 2020 and a 10% binding minimum target to be achieved by all Member States for the share of Biofuels in overall EU transport petrol and diesel consumption [CEU 2007].

In order to meet the new targets, the European Council called for an overall coherent framework for renewable energies, which resulted in the Directive on the “Promotion of the Use of Energy from Renewable Sources” [EC 2009]. This new Directive 2009/28/EC, which went into force on 25 June 2009 amends and subsequently repeals the Directives 2001/77/EC and 2003/30/EC [EC 2001, EC 2003].

The main points of the new Directive are:

- Mandatory national overall targets and measures for the use of energy from renewable sources, as well as an indicative trajectory how to reach the targets;

- National Action Plans containing targets for transport, electricity and heating and cooling in 2020;

- Member States shall provide for either priority access or guaranteed access to the grid-system for electricity produced from renewable energy sources;

- Each Member State has to submit a report to the Commission on progress in the promotion and use of energy from renewable energy sources by 31 December 2011, and every two years thereafter. The sixth report to be delivered on 31 December 2021;

- Criteria and provisions to ensure sustainable production and use of Bioenergy and to avoid conflicts between different uses of biomass.

This Directive exceeds the targets set within the White Paper “Energy for the Future: Renewable Sources of Energy” [EC 1997] and the Green Paper “Towards a European Strategy for the Security of Energy Supply” [EC 2000]. The goals were that renewable energies should provide 12% of the total and 21% of electric energy in the European Union by 2010, in order to meet the obligations of CO₂-reductions pledged in the Kyoto Protocol and to lower the dependence on energy imports.
The White Paper target for the cumulative Photovoltaic systems capacity installed in the European Union by 2010 was 3,000 MW, or a 100-fold increase of the capacity in 1995. It was assumed that electricity generation from these PV systems would then be in the order of 2.4 to 3.5 TWh, depending under which climatic conditions these systems are installed. The target was already achieved in 2006 and the cumulative installed capacity at the end of 2008 was 9.5 GW, more than 3 times the original target.

In the autumn of 2005, the Commission presented a second report on the Directive 2001/77/EC containing experiences gained with the application and co-existence of the different support mechanisms [EC 2005]. The report concluded that it is too early to harmonise the support schemes for renewable electricity and that a co-ordinated approach should be followed in order to reach the 2010 targets.

"Due to widely varying potentials and developments in different Member States regarding renewable energies, a harmonisation seems to be very difficult to achieve in the short term. In addition, short term changes to the system might potentially disrupt certain markets and make it more difficult for Member States to meet their targets. Nevertheless, the advantages and disadvantages of harmonisation towards the different current systems have to be analysed and monitored, also notably for the medium to longer term development."

"The Commission considers a co-ordinated approach to support schemes for renewable energy sources to be appropriate, based on two pillars: co-operation between countries and optimisation of the impact of national schemes."

The progress towards the 2010 targets is shown in Figure 18. The new Directive indicated the overall percentage of renewable energies for the different Member States (Fig. 19) as well as the indicative trajectory (Fig. 20) how to reach it [EC 2009]. The decision on what kind of technologies to utilise in order to reach the national targets is left to the Member States. By 30 June 2010 the Member States have to notify the Commission about their National Renewable Energy Action Plans.

Fig. 18: Electricity generation in TWh from renewable energies in the European Union (Status 2005)
Fig. 19: Share of renewable energies in the European Union in 2020

Fig. 20: Trajectory to reach the share of renewable energies in the European Union in 2020
7.1 Market and Implementation in the European Union

The market conditions for Photovoltaics differ substantially from country to country. This is due to different energy policies and public support programmes for renewable energies and especially Photovoltaics, as well as the varying grades of liberalisation of domestic electricity markets. Between 2001 and 2008, installations of Photovoltaic systems in the European Union increased more than ten times and reached 9.5 GW cumulative installed capacity at the end of 2008 (Fig. 21) [Sys 2009].

A total of about 24 GW of new power capacity was constructed in the EU last year (Fig. 22) [Ewe 2009]. Out of this, 8,480 MW (35%) was wind power; 6,930 MW (29%) gas fired power stations; 4,590 MW (19%) PV; 2,490 MW (10%) oil; 760 (3%) MW coal fired power stations; 470 (2%) MW hydro, 160 MW (0.7%) biomass\(^\text{14}\) 100 MW (0.4%) CSP and 60 MW (0.3%) nuclear power capacity. The renewable share of new power installations was 57% in 2008.

In 2008, Spain was the biggest market due to the almost five-fold increase from 560 MW in 2007 to about 2.7 GW in 2008 [Epi 2009, Sys 2009]. This was more than twice the expected capacity and was due to an exceptional race to install systems before the Spanish Government introduced a cap of 500 MW on the yearly installations in the autumn of 2008.

Germany was the second largest single market, with around 1.5 GW. Since 2005 the market data are only estimates, as no plant registrar exists so far. Such a registrar was finally introduced for new installations from the beginning of 2009, as the new feed-in tariffs under the 2008 revision of the “Erneuerbare-Energien-Gesetz” (EEG) are now coupled to the market size of the year before. This led to significant discrepancies of different estimates, which arise from the different data collection methods, ranging from installer surveys to grid operator surveys and inverter sales statistics. Therefore,\(^\text{14}\) Estimated from the linear extrapolation of AEBIOM, H. Kopetz, Bioenergy markets in Europe, Presentation at the European Union Sustainable Energy Weeks, 9 - 13 February 2009

Fig. 21: Cumulative installed grid-connected PV capacity in EU + CC.
Note that capacities do not seem to correlate with solar resources.
it is difficult to verify the different numbers. However, it is clear that more than 50% of the EU 27 PV installations are in Germany (Fig. 21).

The annual statement of the German Federal Energy and Water Association (Bundesverband der Energie- und Wasserwirtschaft – BDEW) on the kWhs actually produced report for 2008 4.4 TWh electricity produced by photovoltaic solar systems [Bde 2009]. The estimate for 2009 is 5.6 TWh [Bde 2008].

As foreseen in the “Erneuerbare-Energien-Gesetz” (EEG) the feed-in tariffs were reviewed and the new law was passed on 6 June 2008 by the Bundestag (Parliament) and on 4 July 2008 by the Bundesrat (Federal Council) [EEG 2004, EEG 2009]. In the revised law, the feed-in tariffs were reduced by more than 12% from 2008 to 2009 and the depression for new systems increases from 5% resp. 6.5% to 8 and 10% in 2010 and 9% in 2011 and after. To limit the monetary effects of the feed-in regime to consumers without introducing a cap, the law has an additional provision to increase or decrease the depression rate if the market growth is above or below a certain volume in 2009, 2010 and 2011 (details see Table 8).

The Italian feed-in tariffs, agreed in July 2005, led to a steep rise in applications in the second half of 2005 and the first half of 2006, but only a moderate increase in the amount of new systems capacity could be observed in 2006. After the end of the first quarter of 2006, applications with more than 1.3 GW were submitted to the “implementing body” Gestore del Sistema Elettrico (GRTN SpA.), 2.6 times more than the 500 MW cap up to 2012. The actual installations in 2006 were only 12.5 MW, far less than the 50 to 80 MW predicted. On 19 February 2007 a Decreto Interministeriale was issued, which changed the national target for cumulative installed PV systems from 2,000 MW in 2015 to 3,000 MW in 2016 [Gaz 2007]. This led to a steep growth in PV installations and 50.2 MW were installed in 2007 and 127 MW in 2008 [Sys 2009]. On 22 June 2009 GSE (Gestore Servizi Elettrici) announced that more than 500 MW of PV systems were connected to the grid [Ges 2009]. According to the applications they received, they estimated that the total installed capacity could increase to about 900 MW in 2009.

Revised feed-in tariffs in France went into force on 26 July 2006 and resulted in a moderate growth of the French PV market. In 2006 and 2007 just 7.6 MW and 12.8 MW were installed, [Sys 2008], despite the rather attractive and cost competitive feed-in tariff for PV installations integrated in a building. Finally in 2008 installation volume picked up and new systems with 44.3 MW were added [Sys 2009].

In November 2009, the French Government announced a new programme to substantially increase the role of renewable energy in France [MEE 2008]. The French Minister for Energy and the Environment, Jean-Louise Borloo stated that France intends to increase the use of solar generated electricity 400 times by 2020 to a total installed capacity of 5.4 GW. The general tariff remains 0.30 €/kWh (0.40 €/kWh in Overseas Departments and Corsica) for 20 years. For building-integrated PV installations, there is a supplement...
of 0.25 €/kWh (0.15 €/kWh in Overseas Departments and Corsica). However, a new tariff category for commercial buildings (0.45 €/kWh) was created and there is no size limitation for commercial rooftop projects that qualify for the tariff. In addition, 50% of the investment costs for residential installations are tax deductible (max. € 8,000 for singles and € 16,000 for couples) and a lower VAT of 5.5% on material and installation costs is applied. Accelerated depreciation of PV systems is possible for enterprises. Regional support is still possible. These tariffs remain valid until 2012 when they will be revisited in the framework of a normal review process.

At the end of 2008 there was still a huge backlog of approx. 400 MW of applications that were awaiting connection. To simplify interconnection procedure of solar PV systems with Electricité de France (EdF), the Government implemented an internet registration procedure for projects up to 450 kW.

The second amendment of the Ökostromgesetz (Eco electricity law) in Austria finally passed the Parliament on 1 August 2008. It is foreseen that Photovoltaic electricity systems with a capacity larger than 5 kW are eligible for an investment subsidy, but the total amount is limited to € 2.1 million. The provisions of the first amendment in 2006, stating that electricity from all renewable energy sources is supported with € 17 million per year and 10% are earmarked for PV, were not changed.

For 2009 € 18 million are available to support new PV systems with a capacity > 5 kW through the Climate & Energy Fund. Applications can be submitted between 4 August 2009 and 30 November 2009 and the system has to be ready by 31 July 2010 at the latest. The support is given as a lump sum of € 2,500 per kWp for free field and roof-added systems and € 3,200 per kWp for building integrated systems.

Greece introduced a new feed-in-tariff scheme on 15 January 2009. The tariffs will remain unchanged until August 2010 and are guaranteed for 20 years. However, if a grid connection agreement is signed before that date, the unchanged FIT will be applied if the system is finalised within the next 18 months.

Already filed applications for permits (> 3 GW) will be served until the end of 2009. The regime for new applications is not yet known. From then on the degression of the tariffs for new systems will be 5% each half year. A 40% grant will still be available on top of the new FITs for most of the systems (minimum investment eligible for grants is € 100,000).

In addition, a new incentives programme, without a cap for small rooftop PV, was introduced in Greece on 4 June 2009. The new programme covers rooftop PV systems up to 10 kWp (both for residential users and small companies). The new FIT is set at 0.55 €/kWh and is guaranteed for 25 years, as well as being adjusted annually for inflation (25% of last year’s Consumer Price Index). An annual degression of 5% is foreseen for newcomers as of 2012.

In addition to the feed-in-tariff, small residential applications are eligible for a 20% tax deduction capped at € 700 per system. Residential users do not have to be registered as “business” with the tax authorities and are exempted from any tax (with the exception of the 19% VAT paid for the initial investment). Small companies are also exempted from any tax as long as they keep the income from PV as untaxed reserves. It is important to note that in order to be eligible for this FIT, a residence has to cover part of its hot water needs by some other renewable source (e.g. solar thermal). The programme was only approved for the mainland grid areas. Islands with autonomous grids will enter the programme in a second phase as soon as an extra rooftop solar capacity is set for each island. A “small works permit” by the building authorities is the only license needed before installing the system. PV façades are not eligible for the new support scheme. However, a PV façade on a commercial building can still benefit from the old FIT regime (i.e. 0.45 €/kWh for 20 years).

It is hoped that these measures will finally spur the Greek PV market which has been sluggish over the last years with just 18.5 MW installed capacity at the end of 2008 [Sys 2009].

On 29 July 2009, the new legislation supporting renewable energy sources and efficient co-production of heat and power was published in Slovakia’s Law Code [Zbi 2009]. Under this law energy companies that generate electrical energy from renewable sources will enjoy a price guarantee for fifteen years. The defined guarantee involves purchase prices set by the Regulatory Office for Network Industries (ÚRSO) and obligatory purchase of this energy for the electrical energy transmission grid. ÚRSO determines the price for electricity produced from renewable energy sources by taking into consideration the type of the renewable energy source, the technology used, the date of launching of the facility and the installed capacity of the facility.

In Slovenia, a new system of feed-in tariffs is under discussion to be implemented in 2009. The main changes for photovoltaics are the introduction of different tariffs for different plant sizes, as well as a differentiation in ground mounted systems, building integrated systems and systems added to buildings. In addition, it is planned to increase the duration of the guaranteed tariffs from 10 to 15 years, as
well as to introduce a yearly degression rate of 7% for new systems until 2013. A regular review of the technology costs is foreseen every five years.

In the UK, the *Energy Act 2008* contains powers for the introduction of Feed-in Tariffs for renewable electricity installations up to a maximum capacity of 5 MW [UKE 2008]. It is planned that a feed-in tariff for renewable microgeneration – this includes PV systems – will be implemented to work in conjunction with the existing scheme of Renewable Obligation Certificates (ROCs) in 2010. In July 2009, the Department of Energy & Climate Change has launched a "Consultation on renewable Electricity Financial Incentives 2009". The following structure for the FITs was proposed:

- A fixed payment from the electricity supplier for every kilowatt hour (kWh) generated (the “generation tariff”).
- Another payment additional to the generation tariff for every kWh exported to the wider energy market (the “export tariff”). Generators will be guaranteed a market for their exports at a long-term guaranteed price. The generator may choose whether to sell exported electricity to the supplier at this guaranteed export tariff, or negotiate a price for exported electricity in the open market.
- In addition, generators will benefit because they will have the opportunity to use that electricity on-site to offset some or all of the electricity they would otherwise have had to buy.

In Table 7 the proposed UK FITs are shown. An annual degression of 7% of the tariffs for new systems is foreseen.

Despite the fact that the European PV production grew again by almost 60% and reached 1.9 GW, the exceptional Spanish market growth and the stable large German market demand did not change the role of Europe as a net importer of solar cells and/or modules. Further capacity expansions and technology progress are necessary to change this in the future and to secure a leading role of the European PV industry.

The support measures for Photovoltaics in the European Union Member States and Switzerland are listed in Table 8.

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**Table 6: Proposed Slovenian Feed-In tariffs in €/kWh**

<table>
<thead>
<tr>
<th>Category</th>
<th>&lt; 50 kW</th>
<th>10 – &lt; 1,000 kW</th>
<th>1 MW – &lt; 10MW</th>
<th>10 MW – &lt; 125 MW</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Building</td>
<td>0.415</td>
<td>0.380</td>
<td>0.315</td>
<td>0.281</td>
</tr>
<tr>
<td>Building Integrated</td>
<td>0.478</td>
<td>0.437</td>
<td>0.363</td>
<td>0.323</td>
</tr>
<tr>
<td>Ground mounted</td>
<td>0.390</td>
<td>0.360</td>
<td>0.290</td>
<td>0.268</td>
</tr>
</tbody>
</table>

**Table 7: Proposed UK Feed-in tariffs in £/kWh**

<table>
<thead>
<tr>
<th>Category</th>
<th>&lt; 4 kW (new build)</th>
<th>&lt; 4 kW retrofit</th>
<th>4 – 10 kW</th>
<th>10 – 100 kW</th>
<th>100 kW – 5 MW &amp; stand alone systems of all</th>
</tr>
</thead>
<tbody>
<tr>
<td>On Building</td>
<td>0.31 £/kWh</td>
<td>0.365 £/kWh</td>
<td>0.31 £/kWh</td>
<td>0.28 £/kWh</td>
<td>0.26 £/kWh</td>
</tr>
<tr>
<td>Building Integrated</td>
<td>0.365 £/kWh</td>
<td>0.429 £/kWh</td>
<td>0.365 £/kWh</td>
<td>0.329 £/kWh</td>
<td>0.306 £/kWh</td>
</tr>
<tr>
<td>Ground mounted</td>
<td>0.390 £/kWh</td>
<td>0.360 £/kWh</td>
<td>0.290 £/kWh</td>
<td>0.268 £/kWh</td>
<td></td>
</tr>
</tbody>
</table>
The Ökostromverordnung 2009 (eco electricity degree) set the following new tariffs for 2009 (only for PV systems covered by the Ökostromgesetz (Eco Electricity Law).

- System size < 5 kW: 0.4598 €/kWh
- System size 5 to 10 kW: 0.3998 €/kWh
- System size > 10 kW: 0.2998 €/kWh

2009: Investment subsidies for systems up to 5 kWp.

Some of the Federal States have additional investment support schemes.

---

### Belgium

Green Certificates (with guaranteed minimum price): 0.15 – 0.65 €/kWh depending on size and region (Brussels 10 years, Wallonia 15 years); Flanders from 1 January 2006: 0.45 €/kWh for 20 years.

Net meeting possible for systems smaller 10 kWp

Investment grants between 10% and 50% are available depending on the region and legal status of the applicant.

Tax reduction available

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### Bulgaria

In November 2008 the duration of FIT payments was changed from 12 to 25 years. From 1 April 2009 on only systems with a capacity of a maximum of 10 MW are eligible for the tariff. The tariffs are:

- 0.850 BGN/kWh (0.4346 €/kWh)\(^{15}\) for systems up to 5 kW
- 0.755 BGN/kWh (0.3860 €/kWh) for systems < 5 kW and ≥ 10 MW

Up to 20% of the project investment can be financed with a reduced interest loan from the Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL)

\(^{15}\) Exchange rate: 1 € = 1.9558 BGN

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**Table 8: Support mechanisms for Photovoltaics in the European Union and Switzerland**
Investment grants for households, other entities and organisations, not engaged in economic activities are limited to a maximum 55% of the eligible costs and the maximum grant is 16.5 k€ (CY£ 9.500). For enterprises, the grant is 40% of eligible costs and the maximum amount of the grant is 12 k€ (CY£ 7.000).

Since 2007 feed-in tariffs guaranteed for 15 years for systems up to 20 kW capacity:

Without investment subsidy
- 0.224CY£/kWh (0.415 €/kWh)\(^{16}\) for households
- 0.196CY£/kWh (0.363 €/kWh) for enterprises.

With investment subsidy
- 0.12CY£/kWh (0.222 €/kWh).

\(^{16}\text{Exchange rate: 1 € = 0.5401 CYP}\)

Czech Republic

Feed-in tariff for 20 years. Annual prices are set by the Energy Regulator. Producers of electricity can choose from two support schemes:

- **Fixed feed-in tariff 2009 [Cze 2008]:**
  - Systems commissioned after 01/01/09:
    - ≤ 30 kW: 12.890 CZK/kWh (0.497 €/kWh)\(^{17}\)
    - > 30 kW: 12.790 CZK/kWh (0.493 €/kWh)
  - Systems commissioned in 2008: 13.730 CZK/kWh (0.530 €/kWh)
  - Systems commissioned between 01/01/06 and 31/12/07:
    - 14.080 CZK/kWh (0.543 €/kWh)
  - Systems commissioned before 01/01/06: 6.71 CZK/kWh (0.259 €/kWh)

- **Market price + Green Bonus; Green Bonus 2009**
  - Systems commissioned after 01/01/09:
    - ≤ 30 kW: 11.910 CZK/kWh (0.459 €/kWh)
    - > 30 kW: 11.810 CZK/kWh (0.456 €/kWh)
  - Systems commissioned in 2008: 12.750 CZK/kWh (0.492 €/kWh)
  - Systems commissioned between 01/01/06 and 31/12/07:
    - 13.100 CZK/kWh (0.505 €/kWh)
  - Systems commissioned before 01/01/06: 5.73 CZK/kWh (0.221 €/kWh)

Income is exempt from taxes (Act No. 589/1992 on income tax)
Operators may receive subsidies under the European Structural Funds or national programmes.

\(^{17}\text{Exchange rate: 1 € = 25.92 CZK}\)
<table>
<thead>
<tr>
<th>Country</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>No specific PV programme, but settlement price for green electricity 60 Øre/kWh (0.08 €/kWh) for 10 years, then 10 more years 40 Øre/kWh.</td>
</tr>
</tbody>
</table>
| Estonia | No specific PV programme, but Renewable Portfolio Standard and tax relief. Feed-in tariff for 12 years for electricity produced out of RES except wind is:  
  - 1.16 EEK/kWh (0.074 €/kWh)\(^\text{18}\) start of operation 2007 – 2009  
  - 0.85 EEK/kWh (0.054 €/kWh) start of operation 2010 ff.  
  \(^\text{18}\)Exchange rate: 1 € = 15.64 EEK |
| Finland | No PV programme, but investment subsidy up to 40% and tax/production subsidy for electricity from renewable energy sources (6.9 €/MWh). |
| France | Feed-in tariff for 20 years  
  Tariffs 2009:  
  - 0.32 €/kWh (0.42 €/kWh in Overseas Departments and Corsica) for 20 years.  
  - For building-integrated PV installations there is a supplement of 0.25 €/kWh (0.15 €/kWh in Overseas Departments and Corsica).  
  - Since 2009 a new category exists: Rooftop installation on commercial buildings (0.45 €/kWh)  
  - 50% of the investment costs are tax deductible. Lower VAT of 5.5% on system costs (without labour). Accelerated depreciation of PV systems for enterprises.  
  - Regional support still possible.  
  - Annual revision according to inflation. |
| Germany | Feed-in tariff for 20 years.  
  Tariffs for new installations in 2009:  
  - System size < 30 kW: 0.4301 €/kWh  
  - System size 30 to 100 kW: 0.4091 €/kWh  
  - System size 100 kW to 1 MW: 0.3958 €/kWh  
  - System size > 1 MW: 0.33 €/kWh  
  - The annual depreciation rate for new systems increased as follows:  
    - System size < 100 kW: 2010 – 8%  
    - System size > 100 kW: 2010 – 10%  
    - From 2011: 9% for all system sizes |
In addition, there is an automatic increase or decrease of the degression rate if the installed capacity is above or below certain values in the year before. In order to monitor this, all new systems which become operational after 1 January 2009 have to be registered in a central PV system register.

- Increase of degression rate by 1% the following year if the following installed capacity is exceeded:

- Decrease of degression rate by 1% the following year if the following installed capacities are not reached:
  2009: 1,000 MW, 2010: 1,100 MW, 2011: 1,200 MW

The former façade integration bonus is cancelled.

---

**Greece**

In January 2009 a new feed-in-tariff regime was introduced in Greece. The tariffs will remain unchanged until August 2010 and are guaranteed for 20 years. However, if a grid connection agreement is signed before that date, the unchanged FIT will be applied if the system is finalised within the next 18 months. Already filed applications for permits (> 3 GW) will be served until the end of 2009. The regime for new applications is not yet known.

Feed-in tariff [€/kWh]:

<table>
<thead>
<tr>
<th>Start of operation</th>
<th>Mainland Grid</th>
<th>Autonomous island grids</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&gt; 100 kW(_p) ≤ 100 kW(_p)</td>
<td>&gt; 100 kW(_p) ≤ 100 kW(_p)</td>
</tr>
<tr>
<td>February 2009:</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>August 2009:</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>February 2010:</td>
<td>0.40</td>
<td>0.45</td>
</tr>
<tr>
<td>August 2010:</td>
<td>0.392</td>
<td>0.441</td>
</tr>
</tbody>
</table>

From then on the degression of the tariffs for new systems will be 5% each half year.

A 40% grant will still be available on top of the new FITs for most of the systems (minimum investment eligible for grant is € 100,000).

**New since 4 June 2009:**

Rooftop PV systems up to 10 kW\(_p\) (both for residential users and small companies) receive 0.55 €/kWh.

Annual degression of 5% is foreseen for newcomers as of 2012.

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**Hungary**

Support for RES is regulated through the Electricity Act, which entered into force on 1 January 2003.

From January 2008 onwards the feed-in tariff for PV is: 26.46 HUF/kWh (0.10 €\(^{19}\))

\(^{19}\) Exchange rate: 1 € = 265 HUF
Ireland

The Alternative Energy Requirement (AER) Tender Scheme was replaced by a new Renewable Energy Feed in Tariff (ReFIT) scheme in 2006. However, PV is not included.

Italy

Feed-in tariff guaranteed for 20 years. 2% decrease for new systems each year. National target of 2,000 MW for 2015 was changed to 3,000 MW in 2016 [Gaz 2007].

2009 Tariffs:

<table>
<thead>
<tr>
<th>Nominal Power</th>
<th>not integrated</th>
<th>partly integrated</th>
<th>building integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 3 kWp</td>
<td>0.392 €/kWh</td>
<td>0.431 €/kWh</td>
<td>0.480 €/kWh</td>
</tr>
<tr>
<td>3 – 20 kWp</td>
<td>0.372 €/kWh</td>
<td>0.412 €/kWh</td>
<td>0.451 €/kWh</td>
</tr>
<tr>
<td>&gt; 20 kWp</td>
<td>0.353 €/kWh</td>
<td>0.392 €/kWh</td>
<td>0.431 €/kWh</td>
</tr>
</tbody>
</table>

The following additions exist:

- 5% bonus if in the case of a non-integrated system 70% of the electricity is used by the producer.
- 5% bonus for all systems on schools and public health buildings, as well as for all public buildings of communities with less than 5,000 inhabitants.
- 5% bonus for integrated systems on farms and if cladding of asbestos cement is substituted.
- Reduction VAT from 20% to 10%.

Latvia

Feed-in tariff for RES, but not PV specific:

Licensed before 01.06.2001: double the average sales price (~ 0.101 €/kWh) for eight years, then reduction to normal sales price.

Licensed after 01.06.2001: Regulator sets the price.

The feed in system has been amended through Regulation No 503 on Electricity Production from RES (in force since August 2007), but without PV provisions.

A national investment programme for RES has been running since 2002.

Lithuania

No specific PV support. National Control Commission for Prices and Energy approves long-term purchase prices for renewable electricity, and grid operators must give priority to its transport.
In October 2007, the Dutch Government published a new regulation for a feed-in premium for renewable energy. The new support mechanism, called SDE (‘Stimuleringsregeling duurzame energieproductie’) resembles the old MEP premium system. Producers will get a premium covering extra costs on top of the wholesale energy price for a number of years.

For 2009 the guaranteed price for electricity generated with small PV systems (0.6 – 15 kWp) is 0.273 €/kWh and 0.076€/kWh for larger systems.

On 6 April 2009 a feed-in scheme for 20 MW (15 MW small and 5 MW large systems) in 2009 was announced. The FIT was set to 0.526 €/kWh for small and 0.459 €/kWh for large systems. The cap was reached within a short time period.

Investment subsidies are available, administered with yearly calls.

Tax reductions are available.

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**Luxembourg**

A support scheme was set with a “Règlement Grand Ducal” in September 2005. The Règlement had a cap of 3 MW by 2007. The feed-in tariffs have been amended in February 2008. The new tariffs are in force for installations which became operational after **1 January 2008**. Tariffs are guaranteed over 15 years with simpler administrative procedures. They are differentiated according to technology and capacity. Some tariffs are regressive. For Photovoltaics, this tariff is set as follows:

- System size ≤ 30 kW: 0.42 €/kWh
  (with an annual depression rate of 3%)
- System size 31 to 1,000 kW: 0.37 €/kWh

In addition, investment subsidies are available to private companies (Framework Law of Economy Ministry - Framework Law of the Ministry of Middle Classes), communes (Environment Protection Fund of the Environment Ministry), farmers (Law from the Agriculture Ministry supporting rural development) and households (Regulation of 21 December 2007 of the Environment Ministry) investing in RES-E technologies.

In January 2008, new grants for households entered into force to promote RES-E: Investment aid amounts to 30% of the investment for all PV panels.

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**Malta**

Net metering for electricity from PV systems. At the moment it is difficult to determine the value due to the fact that an energy surcharge, which changes every two months, is applied.

Surplus exported to the grid: 0.07 €/kWh.

Grant for roof-top PV installations.

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**Netherlands**

In October 2007, the Dutch Government published a new regulation for a feed-in premium for renewable energy. The new support mechanism, called SDE (‘Stimuleringsregeling duurzame energieproductie’) resembles the old MEP premium system. Producers will get a premium covering extra costs on top of the wholesale energy price for a number of years.

For 2009 the guaranteed price for electricity generated with small PV systems (0.6 – 15 kWp) is 0.273 €/kWh and 0.076€/kWh for larger systems.

On 6 April 2009 a feed-in scheme for 20 MW (15 MW small and 5 MW large systems) in 2009 was announced. The FIT was set to 0.526 €/kWh for small and 0.459 €/kWh for large systems. The cap was reached within a short time period.

Investment subsidies are available, administered with yearly calls.

Tax reductions are available.
Poland

No specific PV programme. In January 2007, changes in the Energy Law Act were made resulting in the requirement of an energy generation licence regardless of the power installed (previously required only > 50 MW).

An excise tax exemption on RES-E was introduced in 2002. It amounts to 0.02 PLN/kWh (0.483 €/cent/kWh)\(^2\)

Green certificates are available for all RE technologies. They have a value of about 0.25 PLN/kWh (0.060€/kWh)

\(^2\)Exchange rate: 1 € = 4.137 PLN

Portugal

The Independent Power Producer (IPP) Law under which a feed-in tariff scheme for PV up to 150 MW was operated is currently suspended. In November 2007 the micro-generation scheme was launched and has been fully operational since March 2008. There are two regimes:

- General Regime: this is available to any type of microgeneration source with a maximum capacity of 5.75 kW. The FIT is the same as the regulated tariff (true net-meeting) set annually by the regulator.
- Special Regime: only for renewable energy sources with a capacity up to 3.68 kW. The initial FIT was set at 0.65 €/kWh and is reduced by 5% each time 10 MW installed capacity (not only PV) are reached. In April 2009 the tariff was reduced to 0.6175 €/kWh.

The tariff is guaranteed for the first 5 years (+ the months in the installation year) and then it will be the one actually in force, revised according to the above rules. The cap is increasing by 2 MW each year. All installations must have at least 2 m\(^2\) of solar thermal panels installed to be eligible for the FIT.

Reduction of VAT rate from 21 % to 12 % on renewable equipment, custom duties exemption and income tax reductions (up to € 800 for solar equipment). Investment subsidies are available for SMEs.

Romania

No specific programme for PV. For the promotion of the production of electricity from Renewable Energy Sources, a system of Tradable Green Certificates is in place. For PV systems 1 MWh produced receives 4 GC.

For the period 2005-2012, the annual maximum and minimum value for Green Certificates trading is 27 € per certificate, respectively 55 € per certificate, calculated at the exchange rate established by the Romanian National Bank, for the last working day of December of the previous year.

The penalty level is 0.84 €/kWh.
New feed-in tariff with cap of 400 MW + 100 MW (addition for ground based systems) were decided on September 2008, with a provision that two thirds of the 400 MW installations will be on rooftop.

Current tariffs are:

- 0.34 €/kWh < 20 kWp; building integrated and rooftop
- 0.32 €/kWh > 20 kWp; building integrated and rooftop, max. 2 MW
- 0.32 €/kWh ground mounted systems up to a maximum size of 10 MW

New feed-in tariff in 2008 for new PV systems and those which became operational after 1 January 2006 (Current Budget cap: CHF 16 million or € 10 million).

Tariff guaranteed for 25 years. Tariff degression for new plants of 8% from 2010:

<table>
<thead>
<tr>
<th>Nominal Power</th>
<th>Ground mounted</th>
<th>Rooftop [CHF/kWh (€/kWh)]</th>
<th>Building integrated</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 10 kWp</td>
<td>0.65 (0.406)</td>
<td>0.75 (0.469)</td>
<td>0.90 (0.563)</td>
</tr>
<tr>
<td>10 – 30 kWp</td>
<td>0.54 (0.338)</td>
<td>0.65 (0.406)</td>
<td>0.74 (0.463)</td>
</tr>
<tr>
<td>30 – 100 kWp</td>
<td>0.51 (0.319)</td>
<td>0.62 (0.389)</td>
<td>0.67 (0.419)</td>
</tr>
<tr>
<td>&gt; 100 kWp</td>
<td>0.49 (0.306)</td>
<td>0.60 (0.375)</td>
<td>0.62 (0.389)</td>
</tr>
</tbody>
</table>

Investment subsidies in the framework of a PV demonstration programme.

Reduced VAT. Renewable Obligation, but not PV specific.
As depicted in Table 8, 17 out of 27 Member States and Switzerland have already introduced feed-in tariffs. However, the efficiency of this measure to increasingly exploit these countries’ PV-potential varies considerably in function of the details in each national regulation. In those States where the tariff does not cover the expenses, impact is very limited. In some other States there is a motivating tariff, but its effectiveness is limited due to

- fulfilling the cap too early,
- too short a period of validity for the guaranteed increased tariff, or
- administrative requirements being too complicated or even obstructive.

Only in those countries in which the tariff has been high enough to recuperate the investment cost in a reasonable time, and a set cap realistic enough, have PV installations increased and competition in production and trade developed substantially. From the socio-economic data at hand, feed-in tariffs should be designed to potentially enable a pay-back of the initial investment within 10 to 12 years and should be combined with a built-in “sun-set”. Such a decrease of the guaranteed tariff by a certain percentage each year compensates early technology users, enforces realistic price reductions, if well designed, and offers a long-term perspective for investors and producers of solar systems.

The New Member States and Candidate Countries still have much lower installation figures, despite good to very good solar resources, in some States with up to 1,600 kWh/kWp (Cyprus, Malta, Romania, Bulgaria, and South-East Hungary). Even in the Baltic States yearly average values of more than 800 kWh per year are possible for a 1 kWp system, which is comparable to Northern Germany [Sur 2004].

An important advantage for feed-in tariffs comes to light when analysing the effectiveness with which individuals are motivated – i.e. hundreds and thousands of private (domestic) investors, who have relatively easy access to grid connection, standardised accountability and last but not least, neighbourhood pride – an ideal situation for intrinsically decentralised PV-energy. Where local common action (at village or town level) or “locally centralised” investment gives better revenue, the market automatically plays its efficiency-enhancing role. Developments threatening electrical grid stability in terms of demand (e.g., large increase of air conditioning units in the Mediterranean EU) could be compensated much more economically, ecologically and socially balanced by decentralised generation and injection – partly avoiding expensive grid reinforcements. In addition, jobs would be created regionally in installation and maintenance businesses.

Stable political and socio-economically viable frame conditions do not only convince private and commercial investors to install Photovoltaic power plants, but also stimulate the investment in new production capacities for solar cells and modules. Especially in Germany and Spain, the most dynamic markets in Europe, the production capacities for solar cells and modules have increased faster than in the other European countries (Fig. 21). It is interesting to note that with

![Fig. 23: 2008 annual production of the 10 largest PV manufacturers in Europe [Pvn 2009]](image)
the expansion of the Italian, French and Czech markets, also the number of solar manufacturing companies in these countries increased.

Since 1999, the majority of investments in solar cell production facilities in Europe were made in Germany and Spain – the two countries that offered so far the most stable and realistic legal framework conditions for citizens investing in a PV system. Only two of the current top-ten European manufacturers hold this position since 2000.

Based on information provided by the industry, Greenpeace and EPIA have assumed in their new study “Solar Generation V – 2008” that 10 jobs are created per MW during production and about 33 jobs per MW during the process of installation [Gre 2008]. Wholesaling of the systems and indirect supply (for example in the production process) each create 3-4 jobs per MW. Research adds another 1-2 jobs per MW. Based on this data the employment figures in Photovoltaics for the European Union was estimated to be well above 100,000 in 2008. This corresponds quite well with figures reported from 48,000 jobs [Bsw 2009] reported for Germany and 41,700 (15,400 permanent and 26,300 temporaries) for Spain [Aso 2009]. However, the Spanish Photovoltaic Industry Association estimates that the employment numbers in Spain will drop to 13,900 (11,300 permanent and 2,600 temporaries) due to the installation cap to 500 MW. For 2009 the employment figures in Photovoltaics for the European Union were estimated to be in the range of 85,000 to 90,000.

In January 2007, the European Commission published a Communication to the Council and the European Parliament entitled “Renewable Energy Road Map – Renewable Energies in the 21st Century: Building a More Sustainable Future” [EC 2007]. In this communication the progress of the Member States towards achieving the Renewable Electricity Directive 2001/77/EC was cited as:

The European Union has made most progress in the electricity sector. Here, with policies and measures currently in place, the European Union will probably achieve a share of 19% in 2010. However, progress has been uneven across the EU, with Member States with a stable regulatory framework performing best.

Concerning the impacts of Renewable Energy use the communication states:

The European Council in March 2006 decided to refocus the Lisbon Strategy23 on jobs and growth24. The renewable energy sector in the EU has achieved global leadership and has a turnover of € 20 billion and employs 300 000 people [Ere 2005]. In order to maintain this role, the EU needs to continue to expand the deployment of renewable energy technologies in the EU. Studies vary in their estimates of the GDP impact of increasing the use of renewable energy, some suggesting a small increase (of the order of 0.5%), and others a small decrease. Studies also suggest that support for renewable energy will lead to a small net increase in employment. Much of the economic activity generated by support for renewable energy is located in agricultural areas, often in peripheral regions.

This is well in line with various studies about the job and local wealth creation effect of Renewable Energies [Epi 2004, Ere 2004, Ike 2005]. Also the German Solar Industry Association reported that despite the fact that a significant amount of the solar cells installed in PV systems in Germany are imported, more than 65% of the added value stays within the German economy [Bsw 2009].

Electricity generated with Photovoltaic systems has additional positive benefits for the European economy in the long run. First, with increasing installations of Photovoltaic systems, the electricity generated can help to reduce the import dependency of the European Union on energy imports. The results of an impact assessment of the European Commission on the effectiveness of support measures for renewable energies in the European Union quoted state [EC 2005]:

Rising oil prices and the concomitant general increase in energy prices reveals the vulnerability and dependency on energy imports of most economies. The European Commission’s DG ECFIN predicts that a $10/bbl oil price increase from $50 to $60/bbl would cost the EU about 0.3% growth and the US 0.35% [EC 2005a]. For the European Union, the negative GDP effect would be in the order of € 41.9 billion from 2005 to 2007.

It is obvious that further price increases worsened the situation and some economic analysts claim that the 2008/2009 economic crisis could be attributed to the rapid increase of the oil prices since 2003 and the spike in July 200825 [IEA 2008].

23 The European Council of Lisbon of March 2000 agreed in its Conclusions on a “new strategic goal for the next decade: to become the most competitive and dynamic knowledge-based economy in the world, capable of sustainable economic growth with more and better jobs and greater social cohesion”.


25 Crude oil prices went up from US$ 26/bbl (June 2003) and spiked at US$ 147.27/bbl (July 2008), source: Oil report IEA.
There are several studies that examine the difficult issue of quantifying the effect of the inclusion of RES in an energy portfolio and the reduction in the portfolio energy price. This is in addition to the employment benefits and the economic benefits of avoided fuel costs and external costs (GHG), money which could be spent within the economy and used for local wealth creation [Awe 2003].

Second, electricity from Photovoltaic systems is generally produced during times of peak demand, or economically speaking, when electricity is most expensive. In addition, Photovoltaic electricity is produced at its best during those times when, in the case of extreme heat and resulting water shortages, thermoelectric power plants have to reduce their output due to a lack of cooling water. During the extreme heat-wave in July 2006, peak prices paid at the European Electricity Exchange (EEX) spot market exceeded the feed-in tariff paid in Germany.

The continuous expansion of the production capacities for solar cells is of particular importance in the light of the export markets for solar systems to the rural areas in Asia, Africa and South America, where about 2 billion people are still without electricity. The Europeans should not lose this future market, also with respect to the possibility it offers for the labour market. In June 2004 the European Photovoltaic Industry Association (EPIA) published its Photovoltaics Roadmap and stated therein: “Failure to act on the recommendations of this Roadmap will be a huge missed opportunity. Europe will suffer the loss of its current strong market position and potential major industry for the future. The PV industry can be of great importance to Europe in terms of wealth and employment, with 59,000 PV related jobs in the EU in 2010 if the targets are met, and a figure of 100,000 jobs would be realistic if export opportunities are exploited.”

A prerequisite for all such developments is that parallel to the public market introduction incentives, electricity generated by solar systems can be freely traded and attain preferential grid access. As PV systems contribute to the avoidance of climatically harmful greenhouse gases, it has to be ensured that electricity generated from solar systems be exempt from eco taxes, where applicable. In addition, one has to enable PV system operators to sell green certificates to CO₂-producers.

In 2006 the European Union already surpassed its own target of 3 GWp cumulative installed capacity for Renewable Electricity from Photovoltaics for 2010. In Figure 24 the growth scenario is shown if the 2001 to 2007 growth rate can be maintained (2008 is not considered due to the exceptional circumstances in Spain). More than 15 TWh of electricity could be generated in 2010. This would be 0.5% of the EU 27 total net production of electricity in 2005. The PV installation growth-rate curve in the European Union exactly mirrors that of wind power, with a delay of approximately 12 years.

The European PV Industry has to continue its impressive growth over the coming years, in order to maintain its market position. This will only be achieved if reliable political framework conditions are created and maintained to enable return on investment for PV investors and the industry alike. Besides this political issue, targeted improvements of the solar cell and system technology are still required.
7.2 PV Research in Europe

In addition to the 27 national programmes for market implementation, research and development, the European Union has been funding research (DG RTD) and demonstration projects (DG TREN) with the Research Framework Programmes since 1980. Compared to the combined national budgets, the EU budget is rather small, but it plays an important role in creating a European Photovoltaic Research Area. This is of particular interest and importance, as research for Photovoltaics in a number of Member States is closely linked to EU funds. A large number of research institutions from small University groups to large research centres, covering everything from basic material research to industry process optimisation, are involved and contribute to the progress of Photovoltaics. In the following, only activities on the European level are listed, as the national or regional activities are too manifold to be covered in such a report.

The European Commission’s Research and Development activities are organised in multi-annual Framework Programmes (FP), with a duration of 4 years. Support for Photovoltaic Research Projects started in 1980. In FP4 (1994 – 1998) 85 projects were supported with a budget of € 84 million. In FP5 (1998 to 2002) the budget was increased to around € 120 million. In the demonstration part, around 40 projects were supported with € 54 million and within the research budget 62 projects were funded with € 66 million. In FP 6 (2002 to 2006) the budget for PV projects fell to € 107.5 million.

In addition to these technology-oriented research projects, there were Marie Curie Fellow-ships and the “Intelligent Energy - Europe” (EIE) Programme. The CONCERTO Initiative launched by the European Commission was a Europe-wide initiative proactively addressing the challenges of creating a more sustainable future for Europe’s energy needs. CONCERTO is supervised by DG Energy and Transport and made available € 14 million for solar related projects.

During the 6th Framework Programme, the PV Technology Platform was established [Pho 2007]. The aim of the Platform is to mobilise all the actors sharing a long-term European vision for Photovoltaics. The Platform developed the European Strategic Research Agenda for PV for the next decade(s) and gives recommendations for its implementation to ensure that Europe maintains industrial leadership [Pho 2007a].

For the first time, the 7th EC Framework Programme for Research, Technological Development has a duration of 7 years and runs from 2007 to 2013. The first call for projects closed on 3 May 2007 for the DG RTD managed projects (FP7-ENERGY-2007-1-RTD) and on 28 June for those managed by DG TREN (FP7-ENERGY-2007-2-TREN).

The call motivated the research topics for Photovoltaics as follows: Photovoltaics is the most capital-intensive renewable source of electricity. Currently, the generation costs of grid-connected PV electricity in Europe range from 0.25 €/kWh to 0.65 €/kWh, depending on both local solar irradiation and market conditions. The work will include the development and demonstration of new processes for Photovoltaic equipment manufacturing, standardised and tested building components and the demonstration of the multiple additional benefits of Photovoltaic electricity. Longer term strategies for next generation Photovoltaics (both high-efficiency and low-cost routes) will also be supported. The content of this Area takes into consideration the Strategic Research Agenda (SRA) developed within the European Photovoltaic Technology Platform.

The Commission expects the following impacts from the research activities: Through technological improvements and economies of scale, the cost of grid-connected PV electricity in Europe is expected to be lowered to a figure in the range of 0.10-0.25 €/kWh by 2020. Research and development should lead to reduced material consumption, higher efficiencies and improved manufacturing processes, based on environmentally sound processes and cycles.

The following Projects were selected:

- **FP7-ENERGY-2007-1-RTD**

  - **APPOLON**: Multi-approach for high efficiency integrated and intelligent concentrating PV modules (systems). The project aims at the optimisation and development of Point focus and Mirror Based Spectra Splitting Photovoltaic concentrating (CPV) systems (multi-approach). MJ solar cells will be manufactured by using new materials and deposition technologies. New concepts will be applied for Mirror-based spectra splitting systems which will allow eliminating the cooling needs. Both the optimised and the new technologies will be properly tested in order achieve reliable long life-time CPV systems. The project started on 1 July 2008 and has a duration of 60 months.
    - **Coordinator**: CESI Ricerca Spa., Italy

  - **HETSI**: Heterojunction solar cells based on a-Si c-Si. The project aims to design, develop and test novel a-Si/c-Si hetero-junction solar cell structure concepts with high efficiency. The project covers all aspects of the value chain, from upstream research of layer growth and deposition, to module process and cell interconnection, down to...
upscaling and cost assessment of hetero-junction concept. The project started on 1 February 2008 and has a duration of 36 months.

**Coordinator:** Commissariat à l’Énergie Atomique (CEA), France

- **HIGH-EF:** Large grained, low stress multi-crystalline silicon thin-film solar cells on glass by a novel combined diode laser and solid phase crystallisation process. The project will develop a unique process allowing for high solar cell efficiencies (potential for >10%) by large, low defective grains and low stress levels in the material at competitive production costs. This process is based on a combination of melt-mediated crystallisation of an amorphous silicon (a-Si) seed layer (<500 nm thickness) and epitaxial thickening (to >2 μm) of the seed layer by a solid phase crystallisation (SPC) process. The project started on 1 January 2008 and has a duration of 36 months.

- **IBPOWER:** Intermediate Band Materials and Solar Cells for Photovoltaics with High Efficiency and Reduced Cost. This project pursues the manufacturing of intermediate band materials and solar cells according to the following main strategies:
  - Insertion of transition elements into III – V semiconductor matrices;
  - Use of quantum dot systems to artificially engineer intermediate band solar cells;
  - Development of intermediate band materials and solar cells based on InGaN;
  - Insertion of transition elements into thin-film polycrystalline hosts;

  The project started on 1 February 2008 and has a duration of 48 months.

  **Coordinator:** Institute of Photonic Technology e.V., Germany

- **ROBUST DCS:** Dye Sensitised Solar Cells (DSC) ROBUST DSC aims to develop materials and manufacturing procedures for Dye Sensitised Solar Cells (DSC) with long life-time and increased module efficiencies (7% target). The project intends to accelerate the exploitation of the DSC technology in the energy supply market. The approach focuses on the development of large area, robust, 7% efficient DSC modules using scalable, reproducible and commercially viable fabrication procedures.

  The project started on 1 February 2008 and has a duration of 36 months.

  **Coordinator:** Energy Research Centre of the Netherlands (ECN), The Netherlands

**FP7-ENERGY-2007-2-TREN**

- **SOLASYS:** Next generation Solar Cells and Module Laser Processing Systems. The main objective is to improve and demonstrate new laser-based manufacturing processes and the related manufacturing equipment for the PV industry. Duration of Project: 36 months.

- **ULTIMATE:** Ultra Thin Solar Cells for Module Assembly – Tough and Efficient. The main objective of the project is to demonstrate the production feasibility of PV modules with substantially thinner solar cells (100 μm) than today. Duration of Project: 36 months.

In the framework of the cooperation theme call FP7-ENERGY-2008 two projects were selected (one by DG RTD and one by DG TREN).

- **NACIR:** New Applications for CPV’s: A fast Way to Improve Reliability and Technology Progress

  The aim of the project is to accelerate the learning curve that CPV’s must follow in order to reach the competitive market within 4-5 years with respect to the current flat panel PV systems. The project started on 1 January 2009 and has a duration of 48 months.

  **Coordinator:** Universidad Politécnica de Madrid

- **MetaPV:** Metamorphosis of Power Distribution: System Services from Photovoltaics.

  The main aim of the project is to demonstrate the provision of electrical benefits from photovoltaics (PV) on a large scale. Additional benefits for active grid support from PV will be demonstrated at two sites: a residential/urban area of 128 households with 4 kWp each, and an industrial zone of 31 PV systems with 200 kWp each.

  Duration of the project: 60 months

  **Coordinator:** 3E, Belgium

The second call for projects was launched on 3 September 2008 and the Call specified the following topics in the area of Photovoltaics (ENERGY 2.1):

- **Photovoltaics is the most capital-intensive renewable source of electricity. Research will include the development and demonstration of new processes for Photovoltaic manufacturing, including the manufacturing of**
equipment for the PV industry, new Photovoltaic-based building elements complying with existing standards and codes and the demonstration of the multiple additional benefits of Photovoltaic electricity. Longer term strategies for next generation Photovoltaics (both high-efficiency and low-cost routes) will also be supported.

- **Topic ENERGY.2009.2.1.1: Efficiency and material issues for thin-film Photovoltaics**

  **Content/scope:** Thin-film Photovoltaics has an inherent low-cost potential because its manufacture requires only small amounts of active materials and it is suited to fully-integrated processing and high throughputs. Research is needed to improve device quality and module efficiency, and to develop a better understanding of the relationship between the deposition processes and parameters, the electrical and optical properties of the deposited materials, and the device properties that result. Key issues to be addressed are improvement of understanding of electronic properties of materials and their interfaces, improvement of the quality and stability of transparent conductive oxides (TCOs), and development of advanced methods for optical confinement. Results should be transferred to production lines by the end of the project.

  **Funding scheme:** Collaborative project. Application Deadline 25 November 2008.

  **Expected impact:** Accelerated market development of cost-effective and more efficient thin-film Photovoltaics.

  **Other information:** In order to maximise industrial relevance and impact of the research effort, the active participation of SMEs represents an added value to this topic. This will be reflected in the evaluation. The active participation of relevant Chinese partners could add to the scientific and/or technological excellence of the project and/or lead to an increased impact of the research to be undertaken; this will also be considered by the evaluators.

- **Topic ENERGY.2009.2.1.2: Solar Photovoltaics: Manufacturing and product issues for thin-film Photovoltaics**

  **Content/scope:** Demonstration of standard production equipment and better processes to reduce materials and energy use, achieve higher throughputs and yields, increase recycling rates and improve both the environmental profile and the overall economics of thin-film Photovoltaics. Quality assurance procedures, in-line monitoring techniques, integration and automation of production and processing steps are also needed to improve production yield and module efficiency and reduce production costs. Equipment manufacturers will play a leading role in this development. Knowledge gained in relevant industries outside PV should also be exploited.

  **Funding scheme:** Collaborative project. Application Deadline 29 April 2009.

  **Expected impact:** Improved productivity parameters (e.g. process yield, throughput) and lower costs leading to accelerated market development and market uptake of cost-effective and more environmentally friendly thin-film Photovoltaics.

  **Other information:** This topic is coordinated with the parallel research work. The active participation of key industrial partners and technology suppliers is essential to achieve the full impact of the project. This will be considered in the evaluation. The guidelines for demonstration projects figure in the guide for applicants. The industrial partners should include a realistic and convincing market deployment plan with clear roles, tasks and responsibilities of defined partners if the project is successful.

  Up to two projects may be funded.

- **Topic ENERGY.2009.2.1.3 Support to the coordination of stakeholders’ activities in the field of Photovoltaics**

  **Content/scope:** Major stakeholders in the field of Photovoltaics have established the European Photovoltaic Technology Platform in order to foster cooperation in the field and to design and implement a Strategic Research agenda. This process should be supported by appropriate administrative and communication activities. Administrative activities include the organisation and management of workshops, conferences and meetings among stakeholders. Communication activities will focus on facilitating the flow and exchange of information within the Technology Platform, with other relevant Technology Platforms, and externally; on development and maintenance of IT tools, as well as on the preparation of information leaflets, brochures, reports and other relevant documents.

  **Funding Scheme:** Coordination and support action. Application Deadline 25 November 2008.

  **Expected Impact:** A further deepening of the cooperation of relevant stakeholders would contribute to increasing the efficiency and competitiveness of research in the field of Photovoltaics.

  **Other Information:** Up to one project may be funded.

  For this topic, the EC contribution will be up to 50% of the total eligible costs of the project for all participants, with a maximum contribution of EUR 500,000 for a period of three years.

The evaluation of projects submitted under this Call has been done during the first half of 2009, but the contract negotiations with successful consortia were not finalised at the cut-off date of this report in August 2009.
The third Call for projects was published on 30 July 2009 specifying the following topics in the area of Photovoltaics (ENERGY 2.1):

- **Topic ENERGY.2010.2.1-1: Further development of very thin wafer based c-Si photovoltaics**

  **Contents/scope:** Research will clarify material requirements for the new processing steps involved in production of high efficiency applications on very thin (<100μm) crystalline wafers. The material manufacturing processes will be adapted and the cell technology developed for a major reduction of production costs. The project(s) should address issues related to material requirements and components, device performance and manufacturing of such cells and modules. Development on high efficiency solar cells on very thin (<100μm) crystalline wafers and of their advanced high-throughput manufacturing, including advanced wafer handling and/or the use of temporary carriers should enable the introduction of very thin cells in production lines. Transfer to pilot production should be envisaged at the end of the project(s).

  **Funding scheme:** Collaborative Project.
  **Application Deadline 15 October 2009**

  **Expected impact:** About 90% of the current PV production today still uses wafer-based crystalline silicon technology. The mainstream manufacturing approach for c-Si solar cells is to process wafers of about 180μm thick, which are then assembled into modules. The availability of Si material of the required quality for high efficiency applications is one of the limitations for further improvement. Although considerable progress has already been made in the manufacturing of c-Si modules, there are still possibilities to further reduce their cost. The project(s) are expected to accelerate the move to higher efficiency solar cells (>20%) and thinner silicon wafers (<100μm, and as thin as ~50μm) and hence reduce material intensity and production costs of c-Si modules.

  **Additional information:** The active participation of relevant industrial partners, in particular SMEs, is essential to maximise impact of the project. This will be considered in the evaluation.

- **Topic ENERGY.2010.2.1-2: Development of novel materials, device structures and fabrication methods suitable for thin-film solar cells and TCOs, including organic photovoltaics.**

  **Content/scope:** The conventional thin-film solar cell technologies (Si-based, CdTe, CIGS) have recently made significant progress towards industrial production, and in the same time organic photovoltaics have demonstrated their potential for the future. However further research and development work is needed with the aim to increase the photovoltaic conversion efficiency, enhance the long-term performance stability of devices and decrease the production cost of solar modules. Research and in-depth investigations on innovative materials, inexpensive and low temperature processing routes and alternative device structures should be performed with the objective to reduce optical losses and maximise the use of solar spectrum for efficiency enhancement. This later could be achieved by improving element properties of thin layers and interfaces in thin-film solar cells and transparent conductive oxide (TCO) layers. It is also important to develop low cost and large area scalable inexpensive deposition technologies for the development of highly efficient solar cells, which optimise material utilisation during processing without sacrificing cell performance.

  **Funding Scheme:** Collaborative Project.
  **Application Deadline 30 November 2009**

  **Expected Impact:** At the end of the project the new developments in the thin-film solar cell materials/devices/processing should result in higher efficiency and stable (as demonstrated by accelerated life-time testing) devices.

  **Additional eligibility criterion:** Proposals which do not include coordination with an Indian project will be considered ineligible. Therefore, the EC proposals must identify and include a detailed explanation of the coordinated Indian project submitted in parallel to the Indian Department of Science and Technology (DST).

  **Additional selection criterion:** Proposals will be selected on the condition that their corresponding coordinated Indian project is also selected for funding by the DST. 

  **Additional information:** To ensure a project implementation that reflects a genuine EU-India cooperation, priority in evaluation will be given to proposals involving properly coordinated research activities between Europe and India in the research plan of the two coordinated projects. The active participation of relevant industrial partners and industrial research centres, as well as the exchange of researchers between European Indian participants, are deemed necessary for achieving the expected impact of the project. This will be considered in the evaluation.

- **Topic ENERGY.2010.2.1-3: Development of new concentrator modules and field performance evaluation of Concentrated PV systems**

  **Content/scope:** Multi-junction solar cells have achieved over 40% efficiency under concentrated light. PV systems using these high efficiency cells and operating in the high concentration range between 200 – 1,000 times are under field evaluation. Further research is needed
to improve first the optical efficiency of the systems and the tracking system performance; and second to assess the reliability and efficiency of the module assembly in terms of electrical insulation and, stability and durability of materials. At the end of the project the overall module efficiency should be improved to 30-35 % with the aim to further reduce the cost of electricity generation from Concentrated PV (CPV) systems. Research and in-depth investigations on primary and secondary optics, efficient heat dissipation techniques and improved and cost effective tracking arrangements should be performed in the project. New materials and new concepts should be explored. In parallel to these development two systems of at least 25 – 50kW capacity each should be designed and installed in an appropriate location in India and in Europe respectively. Module indoor rating as well as system’s field performance evaluation and comparison should be carried out. Modelling of the system’s technical performance should help the development of good practice techniques for CPV with special attention to the spectral effects and device temperature on the average energy production.

**Funding Scheme:** Collaborative Project. Application Deadline 30 November 2009

**Expected Impact:** At the end of the project a new module and CPV system should be developed and demonstrate the required reliability according to the current qualification standards. The targeted efficiency should be demonstrated by the system installed in India and Europe. The project should also deliver a manufacturing cost analysis and the generation cost assessment for the 50 kWp systems.

**Additional eligibility criterion:** Proposals which do not include coordination with an Indian project will be considered ineligible. Therefore, the EC proposals must identify and include a detailed explanation of the coordinated Indian proposal submitted in parallel to Indian Department of Science and Technology (DST).

**Additional selection criterion:** Proposals will be selected on the condition that their corresponding coordinated Indian project is also selected for funding by the DST.

**Additional information:** To ensure a project implementation that reflects a genuine EU-India cooperation, priority in evaluation will be given to proposals involving properly coordinated research activities between Europe and India in the research plan of the two coordinated projects. The active participation of relevant industrial partners and industrial research centres, as well as the exchange of researchers between European Indian participants, are deemed necessary for achieving the expected impact of the project. This will be considered in the evaluation.

### 7.2.1 The Strategic Energy Technology Plan

On 22 November 2007 the European Commission unveiled the European Strategic Energy Technology Plan (SET-PLAN) [EC 2007a]. The SET-Plan will focus, strengthen and give coherence to the overall effort in Europe, with the objective of accelerating innovation in cutting edge European low carbon technologies. In doing so, it will facilitate the achievement of the 2020 targets and the 2050 vision of the Energy Policy for Europe. The Communication on the SET-Plan states:

> Europe needs to act now, together, to deliver sustainable, secure and competitive energy. The inter-related challenges of climate change, security of energy supply and competitiveness are multifaceted and require a coordinated response. We are piecing together a far-reaching jigsaw of policies and measures: binding targets for 2020 to reduce greenhouse gas emissions by 20% and ensure 20% of renewable energy sources in the EU energy mix; a plan to reduce EU global primary energy use by 20% by 2020; carbon pricing through the Emissions Trading Scheme and energy taxation; a competitive Internal Energy Market; an international energy policy. And now, we need a dedicated policy to accelerate the development and deployment of cost-effective low carbon technologies.

Within the SET-Plan, Photovoltaics was identified as one of the key technologies and the SET-Plan calls for six different European initiatives, one of them being solar. The Solar Europe Initiative will focus on large-scale demonstration for Photovoltaics and concentrated solar power. The draft of the Solar Initiative was presented in spring 2009 and is now under further negotiations.

During the 23rd European Photovoltaic Solar Energy Conference and Exhibition from 1 to 5 September 2008, the new vision of the European Photovoltaic Industry Association for 2020 was presented. With the help of the SET-Plan, the Association aims to develop the sector in such a way that up to 12% of European electricity should then be generated with Photovoltaic systems. This would correspond to up to 420 TWh of electricity or 350 GWp installed capacity of Photovoltaic electricity systems. To realise this new vision, around 340 GW of new capacity have to be installed between 2009 and 2020. Installations of new Photovoltaic systems would have to increase from around 1.6 GW per annum in 2007 to 4 GW per annum in 2010 and 80 GW per annum in 2020. This corresponds to a CAGR of 37% over the next 12 years. At the same time, electricity generation costs with Photovoltaic systems will have reached grid parity in most of Europe by then.
In June 2009 the European Photovoltaic Industry Association published its study “SET for 2020 – Solar photovoltaic Electricity: A mainstream power source in Europe by 2020”. The study explores different deployment scenarios ranging between 4 and 12%.

The intention of the SET-Plan Initiatives is that they are industry led and for this reason the European Photovoltaic Industry Association (EPIA) is developing an outline of the necessary measures for Photovoltaics. During a Workshop held in Brussels on 25 September 2008, it was agreed that all the necessary research has to be influenced by industry needs, but that certain research topics have to be led by either industry or academia [Epi 2008]. The following categorisation was done:

- **Split the responsibilities between industry and academic research**
  - **Industry-Lead**
    - Upscaling
    - Cost Reduction in the realm of currently commercialised technologies:
      - modules, BOS, Storage (including utilities)
    - Material availability
  - **Academia Lead**
    - Grid Integration + control and Smart Grid;
      - storage solutions (mainly industry lead and cooperation with utilities) this topic must be in both areas
    - Next Generation technologies: high efficiency si-TF, organics TF, breakthrough of c-Si (tbd)
    - Material fundamentals
    - Radically new manufacturing processes?
      - (other industries)

- **Short Term research issues**
  - Grid Integration and stability (BOS), Smart Grid and Storage
  - Solutions for scarce materials hindering the growth targets (e.g. Silver, Indium, Telluride)
  - BIPV (as a construction element)
  - Definition of Life-time, how to measure it (accurately), how to certify
  - Macro economic model “Power Generation”

- **Medium/ Long Term research issues**
  - Fundamental Material Research
  - Next Generation PV Technology (e.g. MC-cells, 22% 50 µm )
  - Focus on “expandable technologies”, e.g. Si Thin-films --> going to high efficiency solutions
  - Radically new mass production processes (e.g. print vs. vacuum deposition; wafers without kerf loss)
  - Module Lifetimes > 35 years

This list is not yet complete, but the basis for further stakeholder consultations. In addition to the research needs, other issues concerning the necessary policy framework, securing human resources and a general awareness campaign were presented. A list of prerequisites included:

- Co-operation with other RES technologies
- Interaction with utilities and grid operators
- Internalisation of external costs
- Liberalised utility market
- Fair and transparent electricity rate structure

One of the boundary conditions to reach the 12% target is a favourable political framework (EU and national) in the Pre-competitive phase, as well as in the phase when Grid parity is reached and beyond. The following necessary supportive national policies for the pre-competitive phase were listed:

- Reasonable-feed in tariffs (7-8% ROI)
- No caps
- Investment security
- Waive of administrative barriers /simplification (one-stop-shop)
- Priority access to the grid
- Support of building codes

Supportive national policies for the grid parity phase and beyond:

- Investment security
- Waive of administrative barriers/simplification
- Priority access to the grid and grid regulation
- Support of Building codes
7.3 Solar Companies

In the following, some European solar cell manufacturers are described briefly. This listing does not claim to be complete, especially concerning the great number of start-up companies. In addition, it has to be noted that information or data for some companies are very fragmented and limited. A lot of the data were collected from the companies’ web-sites.

7.3.1 ErSol Solar Energy AG
ErSol Solar Energy AG Erfurt, Germany was founded in 1997 and is a producer of polycrystalline solar cells and modules. The company went public on 30 September 2005 and was acquired by the Robert Bosch GmbH in 2008. The ErSol Group manufactures and distributes Photovoltaic crystalline and thin-film silicon products. In 2008 the company had a production of 143 MW [Pvn 2009]. According to the company, production capacity at the end of 2009 will be: 280 MW wafers, 280 MW crystalline solar cells and 40 MW thin-films. A further expansion to 830 MW (630 MW Si-cells and 200 MW thin-films) is planned.

In late 2004, the ErSol Group expanded its marketing activities in the field of solar modules, inverters and other components and transferred them to Aimex-Solar GmbH, a 100% owned subsidiary. Some of the modules sold are based on solar cells that are manufactured by ErSol AG, others are based on third-party products purchased by ErSol AG.

A further expansion of the business is planned with the joint venture company Shanghai Electric Solar Energy AG Co. Ltd., Shanghai, People’s Republic of China (SESE Co. Ltd.), which was established in 2005 and in which ErSol AG holds a 35% interest. The module production was officially opened on 28 February 2006 and ErSol is supplying SESE Co. Ltd. with solar cells for the manufacturing of solar modules.

7.3.2 Isofotón
Isofotón, a private-owned company, was set up in Malaga to produce silicon solar cells by Professor Antonio Luque from the Universidad Politécnica de Madrid. In 1985, Isofotón expanded their activities in the solar sector and also started to fabricate solar collectors. In 2008 Isofotón had a production of 96.5 MW and a production capacity of 180 MW [Pvn 2009].

Isofotón teamed up with the utility Endesa and GEA 21. Together with the Andalusian Department of Innovation, Science and Business, they plan to build the first polysilicon plant in Spain [Iso 2007]. The plant will be built in Los Barrios, Cadiz Province of Andalucía, Southern Spain. An initial production capacity of 2,500 tons of solar grade polysilicon is planned for 2009 and a further expansion to 5000 tons in 2010.

In 2007 Isofoton opened a module assembly factory in China and the company is planning to build another one in the United States to be operational 2011 or 2012. Besides silicon solar cells and modules, Isofotón is very active in developing flat-panel concentrator systems based on GaAs solar cells. This kind of system is favourable for areas with a high proportion of direct sunlight and for large-scale solar plants.

7.3.3 Photowatt
Photowatt was set up in 1979 and relocated to Bourgoin-Jallieu in 1991, where the company converts silicon waste into the raw material used for the manufacturing of solar energy cells. At the beginning of 1997, Matrix Solar Technologies, a subsidiary of the Canadian company, ATS (Automation Tooling Systems), acquired Photowatt International and started to expand the production capacities. According to the mother company ATS Automation, Photowatt has currently a production capacity of 60 MW and an expansion of 25 MW is underway [Ats 2009]. Further expansions in the 100 MW range are planned. In 2008 Photowatt had a production of 28 MW [Pvn 2009].

7.3.4 Photovoltech
Photovoltech was set up in 2002 by Total, Electrabel, Soltech and IMEC for the manufacturing and world-wide marketing of Photovoltaic cells and modules. It is located in Tienen (Belgium) and uses the most advanced IMEC technology. According to the company, current production capacity is 80 – 85 MW and an expansion of almost 400 MW to 500 MW is planned. The first phase of the current expansion will add at least 60 MW to be operational at the beginning of 2010.

In 2008 the company had a production of 48 MW of polycrystalline solar cells [Pvn 2009].

7.3.5 Q-Cells AG
Q-Cells AG was founded at the end of 1999 and is based in Thalheim, Sachsen-Anhalt, Germany. Solar cell production started mid 2001 with a 12 MWp production line. In the 2008 Annual Report, the company stated that the nominal capacity had increased to 950 MW by end 2008 and the production of the 520 MW factory in Malaysia should start in the second quarter 2009 [Qce 2009]. 2008 production was 570 MW.

Q-Cells broadened and diversified its product portfolio by investing in various other companies or forming joint ventures. In the first half of 2009 Q-cells has sold some of these holdings, e.g. REC or CSG Solar and has merged one company – Sovello with Sunfilm AG. It now has one fully- and two partially-owned subsidiaries, Solibro (CIGS), Calylyxo GmbH (CdTe) (93%), Flexcell, Switzerland (58.11%), two joint ventures Sovello (former EverQ; 33.33%) and Sunfilm AG (50%), as well as holdings in Solaria Corp., USA (32%).
7.3.6 Renewable Energy Corporation AS

REC’s vision is to become the most cost-efficient solar energy company in the world, with a presence throughout the whole value chain. REC is presently pursuing an aggressive strategy to this end. Through its various group companies, REC is already involved in all major aspects of the PV value chain. The company located in Høvik, Norway has five business activities ranging from silicon feedstock to solar system installations.

In 2005, Renewable Energy Corporation AS (“REC”) took over Komatsu’s US subsidiary, Advanced Silicon Materials LLC (“ASiMI”) and announced the formation of its silicon division business area “REC Silicon Division”, comprising the operations of REC Advanced Silicon Materials LLC (ASiMI) and REC Solar Grade Silicon LLC (SGS) [Rec 2005]. The company is expanding the Moses Plant by adding 10,500 tons of new capacity. Plant III (6,500 tons) is currently in the ramp-up phase and plant IV (4,000 tons) is planned to be ramped-up in the first half of 2010. According to the company about 6,240 tons were produced in 2008 and the production outlook for 2009 was revised to 9,000 tons.

Since 2004, ScanWafer has become a fully owned subsidiary. ScanWafer started wafer production at the end of 1997 and has grown to become one of the world’s largest producers of multicrystalline wafers. In 2008, REC Wafer’s plants produced wafers for approximately 580 MWp. Significant expansion projects at Herøya, Glomfjord and Singapore are underway and if the current expansion projects are completed in 2010, total production capacity should be 1.7 GW [Rec 2009]. REC ScanCell is located in Narvik, producing solar cells. From the start-up in 2003, the factory has been continuously expanding. According to the company, production of solar cells was 132 MW with a capacity at year end of 225 MWp in 2008. Further expansion is under way in Singapore with the ramp-up phase for the 550 MW facility planned for 2010 [Rec 2009].

7.3.7 Schott Solar AG

Schott Solar AG is a fully owned subsidiary of Schott AG, Mainz since 2005 when Schott took over the former joint venture RWE-Schott Solar, except the Space Solar Cells Division in Heilbronn. Schott Solar’s portfolio comprises crystalline wafers, cells, modules and systems for grid-connected power and stand-alone applications, as well as a wide range of ASI® thin-film solar cells and modules. In 2008, the company had a production of 145 MW (134 MW from Germany, 11 MW from US) [Pvn 2009]. For 2008 the production capacity is 220 MW.

Schott Solar uses silicon wafers grown by Edge-Defined, Film-Fed Growth (EFG) developed by Tyco Laboratories and the Mobil Corporation.

Development of amorphous silicon solar cells started at MBB in 1980. Phototronics (PST) was founded in 1988. In 1991 one of the world’s first large-area pilot production facilities for amorphous silicon was built. In January 2008 the company started shipments of modules from its new 33 MW manufacturing facility for amorphous silicon thin-film solar modules in Jena, Germany.


7.3.8 Solar World AG

Since its founding in 1998, Solar World, Germany, has changed from a solar system and components dealer to a company covering the whole PV value chain from wafer production to system installations.

In February 2007, SolarWorld acquired an old computer factory from the Komatsu-Group in Hillsboro (OR), USA [Sol 2007]. The site will have developed into an integrated solar silicon wafer and solar cell production facility with a capacity of 250 MW by 2009+. As a consequence, the SolarWorld Group shifted its solar crystallisation activities from Vancouver (WA), to Hillsboro. In the first stage of the production increase, capacities will be expanded to 100 MW. Production capacities of the solar module factory at Camarillo (CA) were renewed and will reach 150 MW in 2009. A further expansion of the silicon wafer production at Freiberg/Saxony to 1 GW by 2010 is on track. Solar cell production in 2008 was 220 MW (160 MW Germany, 61 MW U.S.) [Pvn 2009].

In December 2008, the joint venture between Solarworld and SolarPark Engineering Co. Ltd. opened its module factory, in Jeonju, South Korea. The factory has a capacity of 150 MW and can be expanded to 1 GW at its present location.

In 2003 the Solar World Group was the first company worldwide to implement silicon solar cell recycling. The Solar World subsidiary, Deutsche Solar AG, commissioned a pilot plant for the reprocessing of crystalline cells and modules.

7.3.9 Solland Solar Energy BV

Solland Solar is a Dutch-German company and was registered in 2003. At the end of 2004 the construction of the factory went underway and start-up of production was in September 2005. At the end of 2007, production capacity was 60 MW and increased to 170 MW in the first half year of 2008. In addition, the company is planning to expand it to 500 MW in 2010. Solland had a production of 52 MW in 2007 [Pvn 2009].

7.3.10 Sovello

Sovello (former EverQ GmbH) is a joint venture between Q-Cells AG (Thalheim, Saxony-Anhalt), REC (Oslo, Norway) and Evergreen Solar Inc. (Marlboro, MA, USA). In June 2006 the first factory to produce 30 MW String-Ribbon™ wafers, solar
cells and solar modules in Thalheim, Germany, was opened. The second factory with 60 MW capacity was then opened on 19 June 2007 and in January 2008 the company laid the cornerstone for a third production plant with 80 MW, bringing the total capacity to 180 MW in 2009. From 2012 the company plans to produce 600 MW. In 2008 Sovello had a production of 94 MW.

7.3.11 Sunfilm AG
Sunfilm AG was founded at the end of 2006 located in Großröhrsdorf, Germany. In July 2009 the company formally merged with Sontor, a subsidiary of Q-Cells. With this merger, the company becomes the largest thin-film company in Europe using amorphous and amorphous/microcrystalline silicon technology with 145 MW. 85 MW are already online (25 MW at the former Sontor site in Thalheim and 60 MW in Großröhrsdorf). Another 60 MW are currently ramped-up at Großröhrsdorf.

7.3.12 Sunways AG
Sunways AG was incorporated in 1993 in Konstanz, Germany, and went public in 2001. Sunways produces polycrystalline solar cells, transparent solar cells and inverters for PV systems. In 2008 the company produced 33 MW. Sunways opened its second production facility with a production capacity of 30 MW in Amstadt, Germany on 9 September 2005. With this expansion, total production capacity rose to 46 MW. The new production facility can be expanded to 80 MW in the future.

7.3.13 Würth Solar GmbH
Würth Solar GmbH & Co. KG was founded in 1999 with the aim of building up Europe’s first commercial production of CIS solar modules. The company is a joint venture between Würth Electronic GmbH & Co KG and the Centre for Solar and Hydrogen Research (ZSW). Pilot production started in the second half of the year 2000, a second pilot factory followed in 2003 increasing the production capacity to 1.3 MW. The Copper Indium Selenide (CIS) thin layer technology was perfected in a former power station to facilitate industrial-scale manufacture.

In August 2008 the company announced the successful ramp-up of their production facilities to 30 MW [Wür 2008]. A further expansion to at least 40 MW in 2009 is planned. For 2008 a production volume of 20 MW is estimated.

7.3.14 Additional Solar Cell Companies

- **AVANCIS GmbH & Co KG** is a joint venture between Shell and Saint-Gobain. The company plans to produce CIS thin-film modules in a new factory to be built in Torgau, Germany. The initial annual capacity is 20 MW and the official start of commercial production was October 2008.

- **Calyxo GmbH** is a subsidiary of Q-Cells AG located in Wolfen, Saxony-Anhalt. The company plans to manufacture CdTe thin-film solar cells. The pilot plant has a production capacity of 25 MW. In 2008 the company started a 60 MW expansion project, which is 2009 in its ramp-up phase.

- **Concentrix Solar GmbH** was founded in 2005 as a spin-off company of Fraunhofer Institute for Solar Energy Systems and is located in Freiburg/Breisgau. Under the brand name FLATCON®, complete, turnkey concentrating photovoltaic power plants on the commercial level are offered. From 2006 until August 2008, the company manufactured its concentrating modules on a pilot production line before a commercial production line with 25 MW capacity started operation in September 2008.

- **CSG Solar AG** was founded in June 2004 by former employees of Pacific Solar, together with Q-Cells and other investors. Based in Thalheim, Germany, the company aims to produce “Crystalline Silicon on Glass” (CSG) solar modules. The ownership of the CSG technology has been acquired from Pacific Solar Pty Ltd. A pilot-line team has been developing the CSG technology since 1995, first as part of Pacific Solar Pty Ltd, Australia, and now as CSG Solar Pty Ltd., a wholly-owned subsidiary of CSG Solar AG. The first factory for CSG Solar AG opened on 15 March 2006 [Csg 2006]. Initial CSG-1 production capacity was 10 MW, but the plant was designed for 25 MW. In April 2007 the company expanded its work-force and moved to 24/7 operation. Current production capacity is given by the company as 13 MW/annum.

- **G24 Innovations Limited** (G24i), headquartered in Cardiff, Wales, manufactures and designs solar modules based on Dye Sensitised Thin-film (DSTF) technology. In 2007 production of dye sensitised solar cells with a roll-to-roll process started.

- **Helios Technologies** located in Carmignano di Brenta (PD), Italy, was established 1981 and manufactures solar cells, modules and Photovoltaic systems. The company produced around 5 MW solar cells in 2006 [Pvn 2007]. According to the company it is expanding its production facility by 30 MW to become operational in 2009.

- **Inventux Technologies AG** was founded in spring 2007 to manufacture amorphous/microcrystalline thin-film silicon solar modules and broke ground for its 33 MWp

- **Johanna Solar Technology GmbH:** In June 2006 the company started to build a factory for copper indium gallium sulphur selenide (CIGSSE) thin-film technology in Brandenburg/Havel, Germany. The technology was developed by Prof. Vivian Alberts at the University of Johannesburg. The company built up a production line with a nominal capacity of 30 MW. In March 2008 the company granted a license to the Chinese company Shandong Sunvim Solar Technology Co. Ltd. for the construction of a thin-film solar module production plant. In November 2008 the solar cell production started and in August 2009, the Robert Bosch GmbH purchased the company.

- **Odersun AG** was founded in 2002 and developed a unique thin-film technology for the production of copper indium sulphide based solar cells. The main investor is Doughty Hanson Technology Ventures, London, and the company has signed an agreement with Advanced Technology & Materials Co. Ltd., which is listed on the Shenzhen Stock Exchange to co-operate in August 2004. The first production line was inaugurated on 19 April 2007. On 26 March 2008 the company laid the cornerstone for its 30 MW expansion project.

- **Pramac Ecopower** is a division of the Pramac SpA Group located in Balerna (Chiasso), Switzerland. The company manufactures mono- and polycrystalline modules and started with the production of amorphous/microcrystalline thin-film solar modules at their 30 MW factory in July 2009. The equipment was supplied by Oerlikon Solar.

- **Scheuten Solar** took over the assets of Flabeg Solar, Gelsenkirchen, in 2003 and is producing standard glass-teslar PV modules (Multisol®) and custom made glass-glass PV modules (Optisol®). The company is developing a spherical copper indium selenide based solar cell. The pilot plant opened on 21 June 2007 and it was announced to build an industrial production plant with a capacity of 250 MW in 2009 [Sch 2007].

- **SOLARTEC** was established in 1993 and is located in the industrial area of Roznov pod Radhostem, in the eastern part of the Czech Republic. The company is a producer of solar cells and modules, as well as a PV system integrator. In 2006 the company had a production capacity of about 30 MW.

- **Solibro GmbH** was established early 2007 as a joint venture between Q-Cells AG (67.5%) and the Swedish Solibro AB (32.5%). In 2009 the company became a 100% subsidiary of Q-Cells. The company develops thin-film modules based on a Copper Indium Gallium Diselenide (CIGS) technology. A first production line in Thalheim, Germany, with a capacity of 30 MWp, started test production in April 2008. The ramp up of the expansion to 45 MW is planned for the second half of 2009. A second line, with 90 MW, is already under construction and the start of production is planned for the end of 2009. Solibro produced 4 MW in 2008.

- **Solterra Fotovoltaico SA** is located in Chiasso, Switzerland and is a private company established in August 1994 as a Research and Development company focused on the development of new technologies in renewable energy. The company produces monocrystalline solar cells.

- **Sulfurcell Solartechnik GmbH** was incorporated in June 2001 and is jointly owned by its founders and investing partners. In 2004, the company set up a pilot plant to scale up the copper indium sulphide (CIS) technology developed at the Hahn-Meitner-Institut, Berlin. First prototypes were presented at the 20th PVSEC in Barcelona in 2005. Production of CIS modules started in December 2005 and in 2006 the company had sales of 0.2 MW. For 2007, a production increase to 1 MW and 2008 to 5 MW was planned. It is foreseen to open the new production site which can be expanded to 75 MW in October 2009.

- **T-Solar Global, S.A.** (T-Solar) was founded in October 2006. In October 2009 a factory with an initial production capacity of 40 MW was inaugurated in Ourense, Spain. The production plant is based on technology from Applied Materials and the company plans to expand the capacity to 65 MW without a date set.

- **VHF Technologies SA**, is located in Yverdon-les-Bains in Switzerland and produces amorphous silicon flexible modules on plastic film under the brand name „Flex-cell“. Q-Cells AG has a 57.1% share in the company. The first production line on an industrial scale of 25 MW became operational in 2008 and is being ramped-up in 2009.

### 7.3.15 Leybold Optics Solar

Leybold Optics is one of the leading providers of vacuum technology, headquartered in Alzenau, Germany. Since 2001 the company has been owned by the Private Equity Fund EQT. Leybold Optics Solar designs, manufactures and
installs complete production systems for the manufacturing of thin-film single junction a-Si and a-Si/µc-Si tandem solar modules, along with the total project support. In addition, they offer various kinds of production equipment for the solar industry.

7.3.16 PV Crystalox Solar plc
PV Crystalox Solar plc arose from the merger of Crystalox Ltd. in Wantage near Oxford, UK, and PV Silicon AG in Erfurt, Germany. The product range includes: solar grade silicon; single crystal ingots, single crystal wafers and multicrystalline wafers. The company went public in June 2007 and is listed on the London Stock Exchange. In February 2009 the new production facility for solar-grade silicon in Bitterfeld, Germany was opened. The annual production is expected to reach its full capacity of approximately 1,800 MT within the next two years. In 2008, wafer production was 230 MW.

7.3.17 Elkem AS
Elkem AS is a subsidiary of Orkla ASA, and one of Norway’s largest industrial companies and the world’s largest producer of silicon metal. In 2004 Elkem acquired a 23% share in the Renewable Energy Corporation, which was increased to 27.5% in 2005 and to 39.73% in 2007. Elkem Solar is developing a cost-effective metallurgical process to produce silicon metal for the solar cell industry. Elkem is industrialising its proprietary solar grade silicon production line at Fiskaa in Kristiansand, Norway. According to the company, the first plant at Fiskaa will have a capacity of 6,000 tons of solar grade silicon after ramp-up.

7.3.18 NorSun AS
NorSun AS is a subsidiary of the technology group SCATEC AS. The Norwegian start-up company was established in 2005 by Dr. Alf Bjøseth, the founder and former president of the Renewable Energy Corporation ASA (REC). The company is specialising in the production of mono-crystalline wafers for the PV industry. According to a press release by the Finnish silicon wafer processing company, Okmetic Oyi, the company signed an agreement to sell its crystal growth technology to NorSun [Okm 2006]. Ramp-up of the 185 MW facility in Årdal – Norway, has started in autumn 2008 and full capacity is expected to be reached in 2009. In addition, NorSun has a 15 MW production in Vanta, Finland and has started the building process for a 350 MW plant in Singapore in August 2008.

7.3.19 Wacker Schott Solar GmbH
Wacker Schott Solar GmbH, a joint venture of Wacker Chemie AG (Munich) and Schott Solar AG (Mainz), was established in 2007. In April 2008 a second factory for the production of silicon wafers for the solar industry was opened in Jena. After just six months’ construction, Wacker Schott Solar has commenced wafer production, and plans to ramp-up the factory’s annual capacity to 50 MW by autumn 2008. In May 2009, the company opened its new manufacturing building in Jena and it is expected that the full capacity of 275 MW will be reached at the end of the year. Total solar-wafer production capacity is set to expand in stages, reaching about 1 GW per year by 2012.

7.3.20 Wacker Polysilicon
Wacker Polysilicon, Burghausen, Germany is one of the world’s leading manufacturers of hyper-pure polysilicon for the semiconductor and Photovoltaic industry, chlorosilanes and fumed silica. In 2008 Wacker increased its capacity to 15,000 tons and produced 11,900 tons of polysilicon. The company plans to increase its production capacity to 35,000 tons at the end of 2011.

7.3.21 OERLIKON Solar
The co-operation of the Institute of Microtechnology (IMT), the University of Neuchâtel (Switzerland) and UNIAXIS, led to the establishment of UNAXIS Solar. In August 2006 the company changed its name to OERLIKON Solar. UNAXIS Solar started operation on 1 July 2003 with the aim to develop the production technology for large-scale production of PV modules, based on the micromorph solar cell concept developed at IMT and Unaxis’s KAI production systems. In the meantime, Oerlikon Solar has developed into a supplier of turn-key production equipment for thin-film silicon solar modules. The technology available is for amorphous silicon, but the amorphous/micromorph tandem cell is under development at the first customers.

In January 2008, NorSun signed a joint venture agreement with the Saudi Arabian companies Swicorp-Joussour (Swicorp) and Chemical Development Company (CDC) [Nor 2008]. The purpose of the agreement is to establish a joint venture company with the aim to build and operate a polysilicon complex in the industrial city of Jubail in Saudi Arabia. The production capacity of polysilicon at the initial plant will be the equivalent of 500 MW per year. Commercial production is planned to commence in 2010. The site will allow for subsequent expansions up to an annual production capacity equivalent to 2,000 MW. NorSun holds a 29.5% stake in the thin-film company Sunfilm AG.
8. **Outlook**

Despite the fact that the majority of the G20\(^\text{26}\) economic recovery packages include “green stimulus” measures, the sum disclosed in May 2009 just amounted to $185 billion (€135 billion), including $35.3 billion (€25.2 billion) for all renewable energies and $22.1 billion (€15.8 billion) for R&D, spread until 2013. Compared to this, the draft of the new Chinese Energy Revitalisation Plan, which is expected to be finalised and published by the end of the year, calls for a substantially higher investments. For the next decade, the plan foresees RMB 3 trillion (€309 billion) investments into new energy, including solar, and more than RMB 4 trillion (€436 billion) into smart-grids. This development clearly indicates that China is strongly supporting its renewable energy industry and will emerge even stronger after the current financial crisis.

\(^{26}\) The Group of Twenty (G-20) Finance Ministers and Central Bank Governors was established in 1999 to bring together systemically important industrialized and developing economies to discuss key issues in the global economy. The inaugural meeting of the G-20 took place in Berlin, on 15-16 December 1999, hosted by German and Canadian finance ministers.

The Photovoltaic Industry has changed dramatically over the last few years. China and Europe overtook Japan as the major producers of solar cells and China has become the major manufacturing place within just five years.

In 2008, China matched Japan in numbers of top ten manufacturers, with three companies: China (Suntech N°3, Yingli Solar N°6, JA Solar N°7); Japan (Sharp N°4, Kyocera N°5, Sanyo N°10). The other top-ten companies consisted of one European company (Q-Cells N°1), one Taiwanese company (Motech N°8) and three companies with production capacities in more than one continent (First Solar N°3, SunPower N°9, Solarworld N°10). Since 1999 the European PV production has grown on average by 50% per annum and reached about 1.9 GW in 2008. The market shares of European and Chinese manufacturers increased from 20% to 26% and from 1% to 32% respectively, whereas the US and Japanese shares decreased to 6 and 17% respectively.

The continuous and consistent support for Photovoltaics in Japan made it possible for the ambitious goal of 1994 to install 200 MWp of PV systems in 2000, to be reached with only a one year delay in 2001. The long-term strategy up until 2010 was another reason why the Japanese Photovoltaic industry had advanced within only 10 years, to take the market lead. However, the stagnation of the Japanese home market and the aggressive growth of production capacities world-wide have led to a reduction in world market shares from around 50% to 17%.
Before the start of the Japanese market implementation programme in 1997, annual growth rates of the PV markets were in the range of 10%, mainly driven by communication, industrial and stand-alone systems. Due to this programme, the introduction of the German Feed-in Law in 1999 and the introduction of feed-in laws all over the world the PV market has increased its growth to over 40% annually during the last years and reached a production volume of 7.3 GWp 2008.

The temporary shortage in silicon feedstock, triggered by the extremely high growth rates of the Photovoltaics industry over the last years, resulted in the market entrance of new companies and technologies. New production plants for polysilicon, advanced silicon wafer production technologies, thin-film solar modules and technologies, like concentrator concepts, were introduced into the market much faster than expected a few years ago.

Even with the current economic difficulties, the increasing number of market implementation programmes world-wide, as well as the overall rising energy prices and the pressure to stabilise the climate, will continue to keep the demand for solar systems high. In the long-term, growth rates for Photovoltaics will continue to be high, even if the economic frame conditions vary and can lead to a short-term slowdown. This view is shared by an increasing number of financial institutions, which are turning towards renewables as a sustainable and lucrative long-term investment. Increasing demand for energy is pushing the prices for fossil energy resources higher and higher. Already in 2007, a number of analysts predicted that oil prices could well hit 100 $/bbl by the end of 2007 or early 2008 [IHT 2007]. After the spike of oil prices in July 2008, with close to 150 $/bbl, prices have decreased due to the world-wide financial crisis and hit a low around 37 $/bbl in December 2008. However, the oil price has rebounded and is back in the 70 $/bbl range in August 2009. It is obvious that the fundamental trend of increasing demand for oil will drive the oil price higher again. In an interview at the beginning of March 2009, the IEA Executive Director Nobuo Tanaka warned that the next oil crisis with oil prices at around 200 $/bbl due to a supply crunch, could be as close as 2013 because of lack of investments in new oil production.

Speculation about future oil prices range from 20 $/bbl in the autumn of 2009 to 95 $/bbl at the end of 2010. A Reuters poll at the end of July 2009 showed that crude oil is expected to average around 73 $/bbl in 2010. These price uncertainties are an additional risk for all our energy dependent economies and the only energy sources which are able to reduce this risk are those which do not need a fuel like wind or solar. Therefore, investments into solar photovoltaic electricity systems are a bank for the future and increase the attractiveness of Photovoltaics.

According to investment analysts and industry prognoses, solar energy will continue to grow at high rates in the coming years. The different Photovoltaic Industry Associations, as well as Greenpeace, the European Renewable Energy Council (EREC) and the International Energy Agency, have developed scenarios for the future growth of PV. The new U.S. and EPIA visions [Zwe 2007, Epi 2009] are not included, as they do not have the same time horizons. Table 17 shows the different scenarios of the Greenpeace/EREC study, as well as the different 2008 IEA Energy Technology Perspectives scenarios.

These projections show that there are huge opportunities for Photovoltaics in the future if the right policy measures are

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<tr>
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<td>1</td>
<td>10</td>
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<td>Greenpeace ([r]evolution scenario)</td>
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<td>10</td>
<td>30</td>
<td>&lt; 60</td>
<td>non competitive</td>
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<tr>
<td>IEA ACT Map</td>
<td>1</td>
<td>22</td>
<td>80</td>
<td>130</td>
<td>600</td>
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<tr>
<td>IEA Blue Map</td>
<td>1</td>
<td>27</td>
<td>130</td>
<td>230</td>
<td>1,150</td>
</tr>
</tbody>
</table>
taken, but we have to bear in mind that such a development will not happen by itself. It will require the constant effort and support of all stakeholders to implement the envisaged change to a sustainable energy supply with Photovoltaics delivering a major part. The main barriers to such developments are perception, regulatory frameworks and the limitations of the existing electricity transmission and distribution structures.

The International Energy Agency’s World Energy Outlook 2008 stated that for their current Reference Scenario, the “Cumulative Investment in Energy-Supply Infrastructure, 2007-2030” would amount to $26 trillion (€18.6 trillion) [IEA 2008a] over $4 trillion (€2.86 million) more then predicted in the WEO 2007. According to this data $13.6 trillion (€9.7 trillion) would be needed for the electricity sector split roughly in equal halves for power generation and for transmission and distribution.

The new figures imply that the EU, with roughly 18.5% of the total world-wide electricity consumption, will have an investment need of almost $105 billion (€75 billion) per year. Distributed generation of renewables can help to reduce investment in transmission costs. Therefore, there is a unique opportunity at the moment to use the need for an infrastructure overhaul to change to transmission and distribution systems which will be capable of absorbing the large new quantities of different renewable energy sources, centralised and decentralised all over Europe and the neighbouring countries.

Due to the long life-time of power plants (30 to 50 years), the decisions taken now will influence the socio-economic and ecological key factors of our energy system in 2020 and beyond. In addition, the 2003 IEA study pointed out that fuel costs will be in the same order of magnitude as investment in infrastructure. The price development over the last five years has exacerbated this trend and increased the scale of the challenge, especially for developing countries.

Two additional scenarios are shown in the World Energy Outlook 2008. A scenario limiting the concentration of Green-House Gases at 450 ppm (ACT Map) and one with 550 ppm (Blue Map). The IEA estimates that the additional costs for the time period from 2010 – 2030 of the ACT scenario of $4.1 trillion (€2.93 billion) are more than covered by the fuel savings of $7 trillion (€5 trillion) during the same time. In the case of the Blue Map scenario, costs of $9.2 trillion (€6.57 billion) are estimated which would only be compensated partially by fuel cost savings of $5.8 trillion (€4.14 billion) due to higher electricity costs. However, the cost difference of $3.4 billion (€2.43 billion) would just be equal on average 0.2% of annual world GDP. The extra cost amounts to $14 (€10) per person and year.

The above-mentioned scenarios will only be possible if new solar cell and module design concepts can be realised, as with current technology the demand for materials like silver would exceed the available resources within the next 30 years. Research to avoid such kind of problems is underway and it can be expected that such bottle-necks will be avoided.

The Photovoltaic industry is developing into a fully-fledged mass-producing industry. This development is connected to an increasing industry consolidation, which presents a risk and an opportunity at the same time. If the new large solar cell companies use their cost advantages to offer lower-priced products, customers will buy more solar systems and it is expected that the PV market will show an accelerated growth rate. However, this development will influence the competitiveness of small and medium companies as well. To survive the price pressure of the big companies, made possible by economies of scale that come with large production volumes, they have to specialise in niche markets with high value added in their products. The other possibility is to offer technologically more advanced and cheaper solar cell concepts.

Europe already reached its 2010 target in 2006 and the production volume in Europe increased again significantly. Additional production capacities will become available over the next years to secure the market position. Japanese manufacturers are increasing their capacities also considerably, but the stagnating home market pushes them for a stronger export orientation where they have to compete with the new rapidly growing PV manufacturers from China and Taiwan and the new market entrants from companies located in India, Malaysia, Philippines, Singapore, South Korea, UAE, etc. Should the current trend in the field of world-wide production capacity increase continue, Europe will only be able to stabilise its market share around 20%, even with a continuation of the impressive growth rates of the last years. At the moment it is hard to predict how the market entrance of the new players all over the world will influence future developments of the markets.

A lot of the future market developments, as well as production increases, will depend on the realisation of the currently announced world-wide PV programmes and production capacity increases. During 2008 and the first half of 2009, the flood of announcements from new companies which
want to start a PV production, as well as established companies to increase their production capacities, again increased. The total capacity announcement during that period was larger than the total available production capacity at the end of 2008. If all these plans are realised, thin-film production companies will increase their total production capacities even faster than the silicon wafer-based companies and increase their market share from the 2007 market share of 10% to around 20 to 25% in 2010. This will have significant impact on the price reduction of PV modules as well as systems.

Already for a few years, we have now observed a continuous rise of oil and energy prices, which highlights the vulnerability of our current dependence on fossil energy sources and increases the burden developing countries are facing in their struggle for future development. On the other hand, we see a continuous decrease in production costs for renewable energy technologies as a result of steep learning curves. Due to the fact that external energy costs, subsidies in conventional energies and price volatility risks are generally not taken into consideration, renewable energies and Photovoltaics are still perceived as more expensive in the market than conventional energy sources. Nevertheless, electricity production from Photovoltaic solar systems have already shown now that it can be cheaper than peak prices in the electricity exchange in a wide range of countries and if the new EPIA vision can be realised electricity generation cost with Photovoltaic systems will have reached grid parity in most of Europe by 2020. In addition, renewable energies are, contrary to conventional energy sources, the only ones to offer a reduction of prices rather than an increase in the future.
9. **Acknowledgements**

In addition to the numerous discussions I have had with international colleagues, as well as literature and internet research, various Government entities, research centres and leading industry companies were visited in China, Japan, the USA and Europe over the last years. I would like to thank all my hosts for their kindness and the time they have taken to receive me, to share their knowledge and to discuss the status and prospects of Photovoltaics.
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Abstract

Photovoltaics is a solar power technology to generate Electricity using semiconductor devices, known as solar cells. A number of solar cells form a solar “Module” or “Panel”, which can then be combined to solar systems, ranging from a few Watts of electricity output to multi Megawatt power stations.

The unique format of the Photovoltaic Status Report combines international up-to-date information about Research Activities with Manufacturing and Market Implementation data of Photovoltaics. These data are collected on a regular basis from public and commercial studies and cross-checked with personal communications. Regular fact-finding missions with company visits, as well as meetings with officials from funding organisations and policy makers, complete the picture.

Growth in the solar Photovoltaic sector has been robust. Yearly growth rates over the last five years were on average more than 40%, thus making Photovoltaics one of the fastest growing industries at present. The PV Status Report provides comprehensive and relevant information on this dynamic sector for the public interested, as well as decision makers in policy and industry.
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