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PV Status Report 2010

Research, Solar Cell Production and Market Implementation of Photovoltaics

August 2010

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Preface

Spiking oil prices at $ 147.27 per barrel in July 2008 and speculations regarding when the oil price will exceed $ 200 per barrel have already become a reality. The price fluctuations of oil prices during the last years, 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.

The IEA estimated that the additional costs compared to the Reference Scenario of $ 26 trillion (€ 20 trillion) would be $ 4.1 trillion (€ 3.15 trillion) and $ 9.2 trillion (€ 7.01 trillion) for the 550 ppm and 450 ppm scenario respectively. On first sight this looks like a lot of additional investment, but it is much less than the continuation of the current annual energy subsidies of $ 550 billion (€ 423 billion) over the same time period which would amount to $ 11 trillion (€ 8.46 trillion).

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 a new Chinese Energy Revitalisation Plan under discussion, the pledged investments in green energy are marginal. It is already obvious that China, which now strongly supports its renewable energy industry, will emerge even stronger after the current financial crisis.

In 2009, the Photovoltaic industry production again increased by more than 50% and reached a world-wide production volume of 11.5 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 reach € 40 billion in 2010 and prices for consumers are continuously decreasing. The trend that thin-film Photovoltaics grew faster than the overall PV market continued in 2009.

The Ninth 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 2010

Arnulf Jäger-Waldau
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1. Introduction

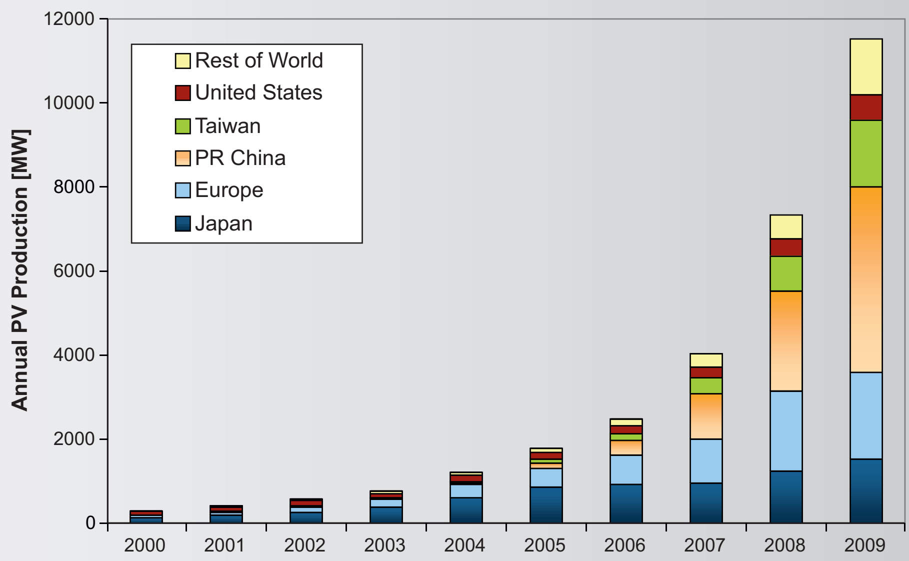
Production data for the global cell production[1] in 2009 vary between 10.5 GW and 12.2 GW. This is again an increase of 40 % to 50 % compared to 2008. The significant uncertainty in the data for 2009 is due to the difficult market situation, which was characterised by a declining market environment in the first half of 2009 and an exceptional boom in the second half of 2009, as well as the fact that some companies report shipment figures, whereas others report sales or production figures. In addition, the difficult economic conditions and increased competition led to a decreased willingness to report confidential company data. The previous tight silicon supply situation reversed due to massive production expansions as well as the economic situation. This led to a price decrease from the 2008 peak of around 500 $/kg throughout 2009, reaching about 50–55 $/kg on average by year's end.

Our own data, collected from various companies and colleagues was compared to various data sources and thus led to an estimate of 11.5 GW (Fig. 1), representing a production growth of about 56 % compared to 2008.

Since 2000, total PV production increased more than 30 fold, with annual growth rates between 40 % and 80 %. The most rapid growth in annual production over the last five years could be observed in China and Taiwan, which together now account for about 50 % of world-wide production.

[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.

Fig. 1: World PV Cell/Module Production from 1990 to 2009 (data source: Navigant [Min 2010, a], PV News [Pvn 2010] and own analysis)



Public-traded companies manufacturing solar products, or offering related services, have attracted a growing number of private and institutional investors. In 2008 world-wide new investments into the renewable energy and energy efficiency sectors increased to a record US $ 155 billion (€ 110 billion[1]), up 5 % from 2007, but the second half of the year saw a significant slowdown due to the unfolding of the financial crisis. This trend continued in the first quarter of 2009 (-47 % compared to Q4 2008), but then started to reverse in the 2nd quarter (+83 % compared to Q1 2009) and resulted in US $ 145 billion (€ 111.5 billion) of new investments for 2009 [Blo 2010]. The recovery continued in the 1st quarter 2010 and resulted in forecast for 2010 in the range of $ 175 – 200 billion (€ 134.6 – 153.8 billion).

In 2008, new investments in solar power surpassed those in bioenergy and were second only to wind with $ 33.5 billion (€ 25.8 billion) or 21.6 % of new capital [UNEP 2009].

The number of consulting companies and financial institutions offering market studies and investment opportunities has considerably increased in the last few years. The fact that the market has changed from a supply- to a demand-driven market and the resulting overcapacity for solar modules has resulted in a dramatic price reduction of almost 50 % over the last two years. Especially for companies in their start-up and expansion phase with limited financial resources, the oversupply situation anticipated for at least the next two years in conjunction with the continuous pressure on average selling prices (ASP) is of growing concern. The financial crisis is adding pressure as it will likely result in higher government bond yields and ASPs have to decline even faster than previously expected to allow for higher project internal rate of returns (IRRs).

Business analysts are confident that despite the current turmoil the industry fundamentals as a whole remain strong and that the overall Photovoltaics sector will continue to experience a significant long-term growth. Following the stock market decline, as a result of the financial turmoil, the PPVX[2] (Photon Pholtovoltaic Stock Index) has declined from its high at over 6,500 points at the beginning of 2008 to 2,330 points in the middle of July 2010 and the market capitalisation of the 30-PPVX companies[3] was € 31.9 billion.

At the end of 2009 only 9 % or $ 16.6 billion (€ 12.8 billion) of the $ 184.1 billion (€ 141.6 billion) G 20 "green stimulus" money from Governments, aimed to help relieve the effect of the recession, had reached the markets. Analysts predict that two thirds of these funds will be spent in 2010 and 2011.

[3] The PPVX is a non commercial financial index published by the solar magazine „Photon" and „Öko-Invest". The index started on 1 August 2001 with 1000 points and 11 companies and is calculated weekly using the Euro as reference currency. Only companies which made more than 50 % of their sales in the previous year with PV products or services are included [Pho 2001].

[4] Please note that the composition of the index changes as new companies are added and others have to leave the index.

Market predictions for the 2010 PV market vary between 9 GW by the Navigant Consulting conservative scenario [Min 2010b], 12.7 GW, EPIA 2010 policy-driven scenario [Epi 2010] and 24 GW by Photon Consulting [Pho 2009]. Massive capacity increases are underway or announced and if all of them are realised, the world-wide production capacity for solar cells would exceed 36 GW at the end of 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 the continuation of the low utilisation rates and therefore a continued price pressure in an oversupplied market. 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.

About 80 % of the current production uses wafer-based crystalline silicon technology. A major advantage of this technology is that complete production lines can 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 temporary 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 between 2005 and 2009. More than 200 companies are involved in the thin-film solar cell production process ranging from R&D activities to major manufacturing plants.

Projected silicon production capacities available for solar in 2012 vary between 140,000 metric tons from established polysilicon producers, up to 185,000 metric tons, includ-

[2] Exchange rate: 1 € = 1.30 $

ing the new producers [Hom 2009] and 250,000 metric tons [Ber 2010]. The possible solar cell production will in addition depend on the material use per Wp. Material consumption could decrease from the current 8 g/Wp to 7 g/Wp or even 6 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. 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, market estimates for 2009 are in the 20 to 30 MW range and for 2010 about 100 MW are expected. 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 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:

- Continuation to expand solar grade silicon production capacities in line with solar cell manufacturing capacities;
- Accelerated reduction of material consumption per silicon solar cell and Wp, e.g. higher efficiencies, thinner wafers, less wafering losses, etc.;
- Accelerated ramp-up of thin-film solar cell manufacturing;
- Accelerated CPV introduction into the market, as well as capacity growth rates above the normal trend.

Further photovoltaic system cost reductions will depend not only on the technology improvements and scale-up benefits in solar cell and module production, but also on the ability to decrease the system component costs, as well as the whole installation, projecting, operation, permitting and financing costs.

2. The Photovoltaic Market

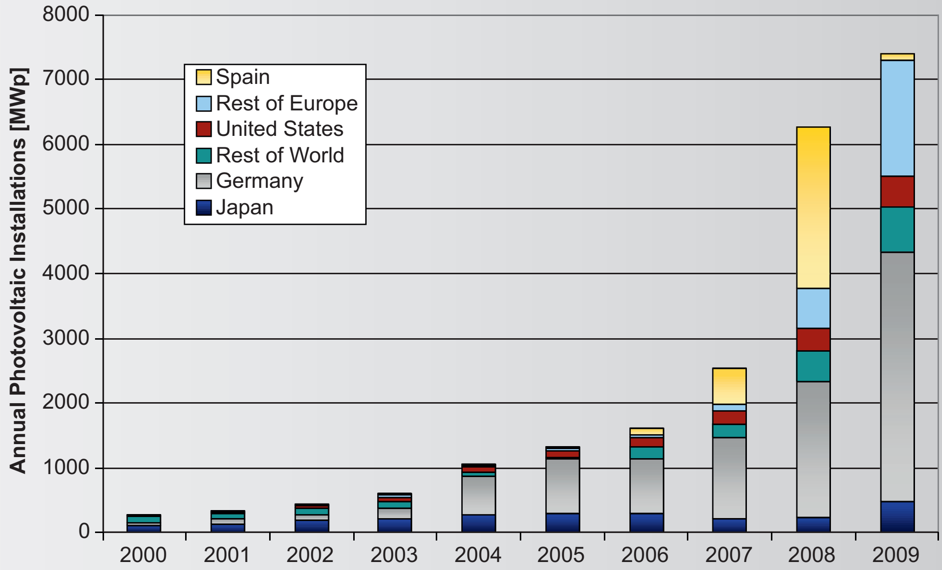
2009 was the year of speculations about a contracting or increasing photovoltaic market. The latest market estimates in spring 2010 came as a surprise for most people. The current estimates are between 7.1 and 7.8 GW, as reported by various consultancies. Like in earlier years our estimates are in between with 7.4 GW (Fig. 2). This represents mostly the grid-connected photovoltaic market. To what extent the off-grid and consumer product markets are included is not clear.

After a slow start, the markets began to pick up pace in the second quarter, but the real boom happened in the last quarter when in Germany alone, according to the German Federal Network Agency, 1.46 GW of new capacity were added [Bun 2010].

With a cumulative installed capacity of 16 GW the European Union is leading in PV installations with a little more than 70 % of the total world-wide 22 GW of solar photovoltaic electricity generation capacity at the end of 2009.

The unexpected growth in 2009 is due to the larger than expected market expansions in a number of countries and the exceptional development in the German market, where in the 4th quarter of 2009 alone 2.3 GW, or 60 % of the annual 3.8 GW installations were connected to the grid [Bun 2010]. The second largest market was Italy with 730 MW followed by Japan (484 MW), the US (470 MW), the Czech Republic (411 MW) and Belgium (308 MW).

Fig. 2: Annual Photovoltaic Installations from 2000 to 2009 (data source: EPIA [Epi 2010], Eurobserver [Sys 2010] and own analysis)



2.1 Asia and Pacific Region

The Asia and Pacific Region shows an increasing trend in photovoltaic electricity system installations. There are a number of reasons for this development ranging from declining prices, heightened awareness, favourable policies and the sustained use of solar power for rural electrification projects. Countries such as Australia, China, India, Japan, Malaysia, South Korea, Taiwan, Thailand and The Philippines show a very positive upward trend thanks to increasing governmental commitment towards the promotion of solar energy and the creation of sustainable cities.

The introduction or expansion of feed-in-tariff is expected to be an additional big stimulant for on-grid solar PV system installations for both distributed and centralised solar power plants in countries such as Australia, Japan, Malaysia, Thailand and South Korea.

The Asian Development Bank (ADB) launched an Asian Solar Energy Initiative in 2010, which should lead to the installation of 3 GW of solar power by 2012. ADB will provide $ 2.25 billion[5] (€ 1.73 billion) to finance the Initiative, which is expected to leverage an additional $ 6.75 billion (€ 5.19 billion) in solar power investments over the period.

2.1.1 Australia

In 2009 more than 56 MW of grid-connected solar photovoltaic electricity systems were installed in Australia, bringing the cumulative installed capacity of grid-connected PV systems to more than 80 MW about the same as the off grid systems [AuG 2010]. Most of the 2009 growth was driven by a Federal Government rebate programme of AUD 8 per watt (5.33 €/W)[6] (capped at AUD 8.000), which combined with Renewable Energy Certificates (RECs), offered the possibility of zero-cost 1 KWp systems. This programme was terminated and it is unclear how the market will develop after all the approved systems are installed in the first half of 2010. At the beginning of 2010, 8 out of the 11 Australian Federal States and Territories had introduces some kind of feed-in tariff scheme for systems smaller than 10 kWp.

The expanded Renewable Energy Target (RET) scheme was proposed in 2009 to encourage additional generation of electricity from renewable energy sources to meet the Government's commitment to achieving a 20 % share of renewables in Australia's electricity supply in 2020. On 9 September 2009 two amendment bills went into force which increased the renewable energy target from 9,500 GWh to 45,000 GWh by 2020 and set Solar Credits (REC Multiplier), which is a mechanism under the expanded RET scheme which multiplies the number of RECs able to be created for the system.

2.1.2 India

For 2009 market estimates for solar PV systems vary between 30 to 100 MW. The launching of the Indian National Solar Mission in January 2010 should give impetus to the markets. The National Solar Mission 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. The short-term outlook until 2013 was improved as well when the original 50 MW grid-connected PV system target in 2012 was changed to 1,000 MW in 2013.

2.1.3 Japan

When the Japanese Residential PV Dissemination Programme ended in FY 2006 after 12 years it had resulted in a cumulative PV system installation of 1,617 MW, out of 1,709 MW total installed PV capacity. However, in FY 2007 the Japanese market declined to 210 MW and only recovered slightly to 230 MW in 2008 [Epi 2010, Ohi 2009]. In general, the end of the Residential PV System Dissemination Programme was considered the main reason for the decrease of new installations, but not so much because of the phase-out of the financial incentive but because this was perceived as lack of political support.

In order to counteract this development METI developed the "Action Plan for Promoting the Introduction of Solar Power Generation" and reinstated an Investment Support Programme at the beginning of 2009 [MET 2008]. Finally the law on the *Promotion of the Use of Non Fossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers* was enacted in 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 became a National Programme with cost burden sharing of all electricity customers. In November 2009 METI started, in the framework the review of the Basic Energy Plan, to look into potential scenarios for the introduction of a feed-in tariff scheme for renewable energies in Japan. In the spring of 2010 a public consultation about the introduction of such a feed-in-tariff scheme was launched.

These measures resulted in a strong recovery performance of the Japanese market in 2009 when more than double of new capacity than in 2008 was added. 484 MW newly installed capacity increased the cumulative installed PV capacity to 2.6 GW.

[5] Exchange rate: 1 € = 1.30 $

[6] Exchange Rate: 1 € = 1.50 AUD

2.1.4 People's Republic of China

Despite the fact that the Chinese PV market more than tripled in 2009 to approximately 160 MW, the home market is still less then 4 % of total Photovoltaic production. This situation will change, but the market will not grow as fast as expected last year, when a New Energy Stimulus Plan was discussed in addition to the various stimulus packages. The unofficial target is 20 GW of cumulative PV installations in 2020. However, in the spring of 2010 it became clear that this New Energy Stimulus Plan would not come soon, but likely be integrated in the overall economic development strategy for the next decade.

In July 2009 a joint notice was released 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 subsidise 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.

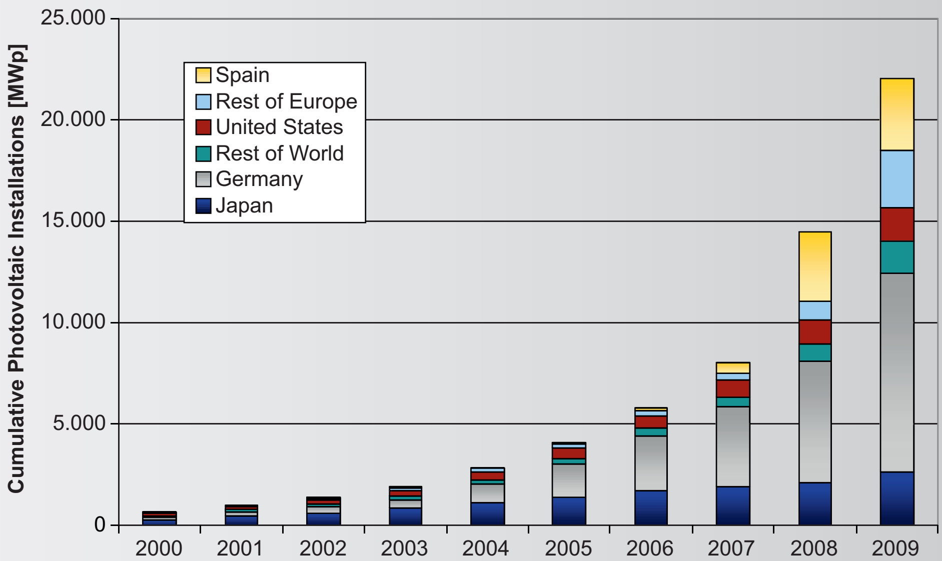
A national plan on renewable energy development issued in 2007 set a target to increase renewable resources to supply 15 percent of its total energy consumption by 2020. In December 2009 China amended its renewable energy law to require electricity grid companies to buy all the power produced by renewable energy generators. According to statements of senior Government officials published in various Chinese media, China will take radical measures to increase the use of new energy in the 12th Five Year Plan (2011-15), a move that reinforces the nation's commitment to improve the energy mix and reduce pollution. According to a recent report by the World Bank, China needs an additional investment of $ 64 billion (€ 49.2 billion) annually over the next two decades to implement an “energy-smart” growth strategy [WoB 2010]. However, the reductions in fuel costs through energy savings could largely pay for the additional investment costs according to the report. At a discount rate of 10 percent, the annual net present value (NPV) of the fuel cost savings from 2010 to 2030 would amount to $ 145 billion (€ 111.5 billion), which is about $ 70 billion (€ 53.8 billion) more than the annual NPV of the additional investment costs required.

2.1.5 South Korea

In 2009 the market in South Korea contracted to about 170 MW after the exceptional year 2008 where almost 300 MW were installed. The reason for this development was that the 500 MW cap on cumulative installations for the feed-in tariff scheme 2008 to 2011 was reached. Despite a 1.3 GW target of cumulative installed solar photovoltaic electricity capacity, the market outlook is unclear due to a missing support policy because only from 2012 a Renewable Portfolio standard was planned.

In January 2009, the Korean Government had 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

Fig. 3: Cumulative Photovoltaic Installations from 2000 to 2009 (data source: EPIA [Epi 2010], Eurobserver [Sys 2010] and own analysis)



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

2.1.6 Taiwan

In June 2009, the Taiwan 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. In December 2009 the Ministry of Economic Affairs (MOEA) announced the 20 years guaranteed feed-in tariffs for solar electricity to be 11.1 NT$[7]/kWh (0.264 €/kWh) to 12.9 NT$/kWh (0.307 €/kWh) in 2010.

2.1.7 Thailand

Thailand enacted a 15-year Renewable Energy Development Plan (REDP) in early 2009, setting the target to increase the Renewable Energy share to 20 % of final energy consumption of the country in 2022. Besides a range of tax incentives, solar photovoltaic electricity systems are eligible for a feed-in premium or "Adder" for a period of 10 years. However, there is a cap of 500 MW which are eligible for the 8 THB[8]/kWh (0.182 €/kWh) "Adder" (facilities in the 3 Southern provinces and those replacing diesel systems are eligible for an additional 1.5 THB/kWh (0.034 €/kWh)). Within the three categories of *PV rooftop systems*, the *Very Small Power Producer Programme* (VSPP) for systems smaller than 10 MW and the *Small Power Producer Programme* (SPP) for systems with a maximum capacity of 90 MW, about 560 MW of PV projects were under consideration, 170 MW of projects were accepted, but without Power Purchasing Agreement (PPA) and for 225 MW PPAs were already signed at the beginning of 2010.

2.1.8 Emerging Markets

- **Malaysia:** The Malaysia Building Integrated Photovoltaic (BIPV) Technology Application Project was initiated in 2000 and at the end of 2009 a cumulative capacity of about 1 MW of grid-connected PV systems has been installed.
  The Malaysian Government officially launched their GREEN Technology Policy in July 2009 to encourage and promote the use of renewable energy for Malaysia's future sustainable development. By 2015, about 1 GW must come from Renewable Energy Sources according to the Ministry of Energy, Green Technology and Water (KETHHA). The Malaysian Photovoltaic Industry Association (MPIA) proposed a five-year programme to increase the share of electricity generated by photovoltaic systems to 1.5 % of the national demand by 2015. This would translate into 200 MW grid-connected and 22 MW of grid systems. In the long-term beyond 2030 MPIA is calling for a 20 % PV share. Pusat Tenaga Malaysia (PTM) and its IEA international consultant estimated that 6,500 MW power can be generated by using 40 % of the nation's house roof tops (2.5 million houses) and 5 % of commercial buildings alone. To realise such targets, a feed-in tariff is under discussion at the moment and it is anticipated that it could be passed in the 3rd quarter of 2010.
  First Solar (US), Q Cells (Germany) and Sunpower (US), have started to set up manufacturing plants in Malaysia, with a total investments of RM 12 billions and more than 2 GW of production capacities. Once fully operational these plants will provide 11,000 jobs and Malaysia will be the world's 6th largest producer of solar cells and modules.

- **The Philipines:** The Renewable Energy Law was passed in December 2008 [RoP 2008]. Under the law the Philippines has to double the energy derived from Renewable Energy Sources within 10 years. In May 2009, the Department of Energy (DoE) published the law's implementing rules and regulations (IRR).
  A major driver is the dramatic electricity demand increase as the DoE has forecasted that 16,550 MW of additional capacity is needed from 2010 to 2030 to meet the population's energy demand. The Remote Area Electrification Subsidy (RAES) Programme aims to support the country's goal of achieving 100 % barangay (village) electrification by 2009 and 90 % household electrification by 2017. At the end of 2009 about 7 MW of PV systems were installed, mainly off-grid.
  SunPower has two cell manufacturing plants outside of Manila. Fab. N° 1 has a nameplate capacity of 108 MW and Fab. N° 2 adds another nameplate capacity of 466 MW.

2.2 Europe and Turkey

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. After a tenfold increase of solar photovoltaic electricity generation

[7] Exchange Rate 1 € = 42 NT$
[8] Exchange Rate 1€ = 44 THB

capacity between 2001 and 2008, the newly installed capacity increased by almost 60 % in 2009 and reached more than 16 GW cumulative installed capacity at the end of the year (Fig. 4) [Bun 2010, Ges 2010, Sys 2010].

A total of about 27.4 GW of new power capacity was constructed in the EU last year and 5.8 GW were decommissioned resulting in 21.6 GW of new net capacity (Fig. 5) [Ewe 2010]. Out of the new installed capacity, 10.2 GW (37 %) was wind power; 6.6 GW (24 %) gas fired power stations; 5.8 GW (21 %) photovoltaic systems; 2.4 GW (9 %) MW coal fired power stations; 580 MW (2.1 %) biomass; 570 MW (2.1 %) oil; 440 MW (1.6 %) waste; 440 MW (1.6 %) nuclear power; 390 MW (1.4 %) hydro and 120 MW (0.4 %) CSP capacity. The renewable share of new power installations was 62 % in 2009.

In the following subchapters, the market development in some of the EU Member States, as well as Switzerland and Turkey, is described.

2.2.1 Belgium

Belgium showed a strong market performance in 2009 with new photovoltaic system installations of 290 MW bringing the cumulative installed capacity to 370 MW. However, most of the installations were done in Flanders, where since 1 January 2006 Green Certificates exist with 0.45 €/kWh for 20 years. In Brussels and Wallonia the Green Certificates have a guaranteed minimum price between 0.15 – 0.65 €/kWh depending on the size of the systems and region (Brussels 10 years, Wallonia 15 years).

2.2.2 Czech Republic

In the Czech Republic photovoltaic systems with more than 400 MW capacity were installed in 2009 bringing the cumulative nominal capacity to 460 MW. The law on the Promotion of Production of Electricity from Renewable Energy Sources went into effect on 1 August 2005 and guarantees a feed-in tariff for 20 years. The annual prices are set by the Energy Regulator. The Producers of electricity can choose from two support schemes, either fixed feed-in tariffs or market price + Green Bonus. The 2010 feed-in rate in the Czech Republic is CZK[9] 12.25 per kilowatt hour (0.48 €/kWh).

In view of the recent rapid expansion of solar photovoltaic electricity system installations, the Czech Government proposed a new law, which will allow the Regulator to increase the annual degression for new systems above the previous 5 % limit. The new law, which was passed by the Senate in April 2010, gives the Regulator the freedom to cut the feed-in tariffs that distributors must pay solar plants as of next year, when it determines that the return on investment into solar plants falls below 11 years.

2.2.3 France

In 2009 France saw a massive growth in new photovoltaic system installations to 285 MW, but about 100 MW were not yet connected at the end of the year. This growth is the result of the 2006 revision of the feed-in tariffs introduced in France in 2000 with Decree N° 2000-1196. The result was a moderate growth of the French PV market in 2006 (7.6 MW) and 2007 (12.8 MW). In 2008 installation volume picked up and new systems with 44.3 MW were added [Sys 2010].

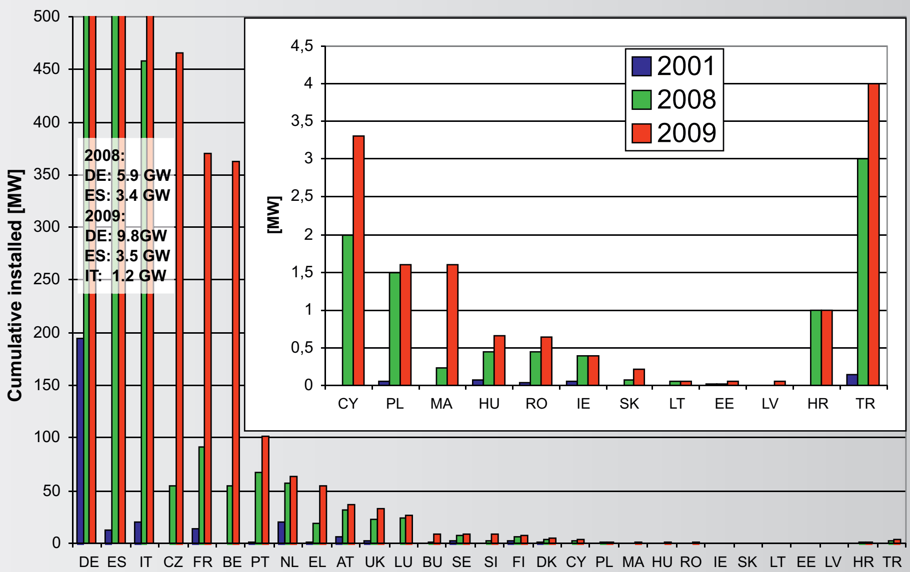


Fig. 4: Cumulative installed grid-connected PV capacity in EU + CC. Note that capacities do not seem to correlate with solar resources.

[9] Exchange rate: 1 € = 25.52 CZK

In November 2008, 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-Louis 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 latest change to the feed-in tariff structure was made in January 2010 [Jor 2010]. The main content of the Regulation is:

- Contract duration 20 years, linked to inflation, but the inflation indexing was reduced to 20 %.
- Additional investment subsidies are available as tax credits. 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.
- Starting from 2012, the tariff for new contracts will annually decrease by 10 %.
- Only 1,500 kWh/kWp per year are bought from any fixed installation in the mainland (2,200 kWh/kWp for tracking) at the tariffs listed below. Any surplus will then be bought at 0.05 €/kWh. In Overseas Departments and Corsica, the caps for fixed and tracking installation are respectively 2200 kWh/kWp and 2600 kWh/kWp.

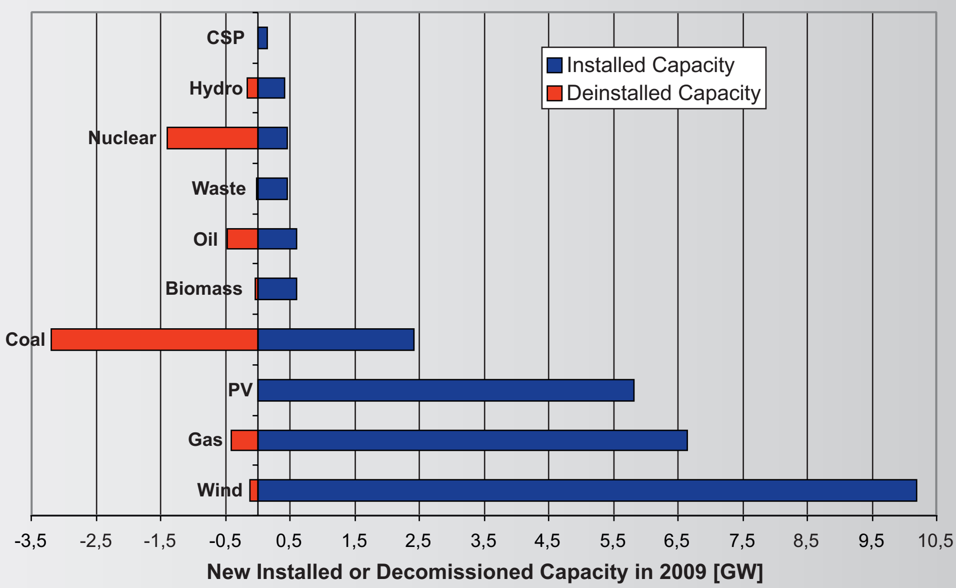
2.2.4 Germany

Germany had the biggest market with estimates in the range of 3.8 to 3.9 GW. The German market growth is directly correlated to the introduction of the Renewable Energy Sources Act or *"Erneuerbare Energien Gesetz"* (EEG) in 2000 [EEG 2000].

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 degression 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 degression rate if the market growth is above or below a certain volume in 2009, 2010 and 2011.

The German market took off after a slow start in the second half of the year. The two main reasons for this were the facts that in September 2009 it became obvious that the installations would be higher than foreseen, triggering the additional 1 % cut in the tariffs from 1 January 2010 on and the change of Government after the general elections in September, which led to an amendment of the Renewable Energy Law in July 2010 and a further substantial cut of up to16 % (in two steps) during 2010. The most often quoted justification for this additional cut is the massive price reduction of more than 30 % for photovoltaic systems in 2009.

Fig. 5: New installed or decommissioned electricity generation capacity in Europe in 2009



2.2.5 Greece

Greece introduced a revised feed-in-tariff scheme in 2009, which foresaw that the tariffs would 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 would be applied if the system is finalised within the next 18 months. For small rooftop PV systems an additional programme was introduced in June 2009. This programme covers rooftop PV systems up to 10 kWp (both for residential users and small companies). The corresponding feed-in tariff was 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. Despite the fact that more than 3.5 GW of PV projects are in the planning pipeline, only 36 MW were actually installed in 2009. At the moment it is unclear how the current financial crisis will affect the PV market.

2.2.6 Italy

Italy moved to the second place with respect to new installations and added a capacity of about 720 MW bringing cumulative installed capacity to 1.2 GW at the end of 2009 [Ges 2010]. 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 70.1 MW were installed in 2007 and 338 MW in 2008 and 720 MW in 2009 [Ges 2010]. The new Regulations of the Conto Energia 2011 – 2013 foresee a 20 % cut in the tariff in 2011, compared to 2010, and are designed to support about 3 GW of new installations.

2.2.7 Spain

Spain is second regarding the total cumulative installed capacity with 3.5 GW. Most of this capacity was installed in 2008 when the country was the biggest market with close to 2.7 GW in 2008 [54]. 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. The reason for the drastic market expansion between 2006 and 2008 was the Spanish Government's approval of the *Plan de Energías Renovables en España* (PER) for 2005 – 2010 in August 2005. The objectives were to cover 12.1 % of Spain's overall energy needs and 30.3 % of total electricity consumption with renewable energy sources by 2010. The generous feed-in tariffs set by the Royal Decree 436/2004, dated 12 March 2004, started the development of the Spanish PV market. In 2007 the Royal Decree 661/2007 was passed with an increased cap of 1,200 MW for PV installations and triggered a run on permits to install multi-megawatt free-field solar photovoltaic electricity systems. This development led to the revision of the Solar PV Legislation in 2008, and the new Royal Decree 1758/2008 which was approved on 26 September 2008. The new decree sets considerably lower feed-in tariffs for new systems and limits the annual market to 500 MW with the provision that two-thirds are rooftop mounted and no longer free field systems. In 2009 this change in legislation resulted in a new installed capacity of about 100 MW.

2.2.8 Other European Countries and Turkey

Despite high solar radiation, solar photovoltaic system installation in Portugal have only grown very slowly and reached a cumulative capacity of 100 MW at the end of 2009. The introduction of a new feed-in tariff scheme in the United Kingdom in 2010 is opening an interesting potential for growth in 2010 and after.

In March 2010, the Turkish Energy Ministry unveiled its 2010 – 2014 Strategic Energy Plan. One of Government's priorities is to increase the ratio of *renewable energy* resources to 30 % of total energy generation by 2023. In line with this announcement, the Turkish Government is preparing a revision of the existing Renewable Energies Law, with the provision of higher feed-in tariffs for solar and wind.

2.3 North America

2.3.1 Canada

In 2009 Canada more than doubled its cumulative installed PV capacity with 70 MW new installed systems. This development was driven by the introduction of a feed-in tariff in the Province of Ontario enabled by the *"Bill 150, Green Energy and Green Economy Act, 2009"*. On the Federal level only an accelerated capital cost allowance exists under the Income Tax Regulations. On a Province level, 9 Canadian Provinces have *Net Metering Rules* with solar photovoltaic electricity as one of the eligible technologies, *Sales Tax Exemptions and Renewable Energy Funds* exist in 2 Provinces and *Micro-Grid Regulations* and *Minimum Purchase Prices* each exist in 1 Province.

The Ontario feed-in tariffs set in 2009 depend on the system size and type as follows:

- Rooftop or ground-mounted ≤ 10 kW
  80.2 ¢/kWh (0.59 €/kWh[10])

- Rooftop > 10 kW ≤ 250 kW
  71.3 ¢/kWh (0.53 €/kWh)

- Rooftop > 250 kW ≤ 500 kW
  63.5 ¢/kWh (0.47 €/kWh)

- Rooftop > 500 kW
  53.9 ¢/kWh (0.40 €/kWh)

- Ground-mounted[11] >10 kW ≤ 10 MW
  44.3 ¢/kWh (0.33 €/kWh)

The feed-in tariff scheme has a number of special rules ranging from eligibility criteria, which limit the installation of ground-mounted PV systems on high yield agricultural land to domestic content requirement and *additional "price adders" for Aboriginal and community-based projects*. Details can be found in the Feed in Tariff Programme of the Ontario Power Authority [Ont 2009].

2.3.2 United States of America

In the USA new installed PV capacities are estimated between 470 and 510 MW. At the moment, Power Purchase Agreement Applications with a two digit GW capacity are in the permitting stage, but it is assumed that only a part of them will be actually realised over the next two to three years. California, New Jersey and Florida account for more than 70 % of the US grid-connected PV market.

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 next milestone was the final approval of the Californian "Million Solar Roofs Plan" or Senate Bill 1 (SB1) in 2006. The *"Energy Improvement and Extension Act of 2008"* as part of H.R. 1424, the *"Emergency Economic Stabilization Act of 2008"* and the *"American Reinvestment and Recovery Act of 2009"* were the next steps to support the implementation of renewable energies and solar photovoltaic electricity generation.

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.

Clean Renewable Energy Bonds (CREBs) were created under the Energy Tax Incentives Act of 2005[12], 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 of new allocations to $ 2.4 billion (€ 1.85 billion[13]). Of this amount, $ 800 million (€ 615.4 million) is available for state, local, and tribal Governments; $ 800 million (€ 615.4 million) for public power providers; and $ 800 million (€ 615.4 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 (€ 923.1 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.

[10] Exchange Rate 1 € = 1.35 CAD
[11] Eligible for Aboriginal or community adder
[12] added Section 54 to the Internal Revenue Code
[13] Exchange rate: 1 € = 1.30 $

3. The Photovoltaic Industry

In 2009 the photovoltaic world market grew in terms of production by approximately 40 to 60 % to 10.5 – 12.2 GW. The market for installed systems about doubled and the current estimates are between 7.1 and 7.8 GW, as reported by various consultancies. 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 3 to 4 GW has therefore to 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.

In addition, the fact that some companies report shipment figures, whereas others report production figures, adds to the uncertainty. The difficult economic conditions added to the decreased willingness to report confidential company data. Nevertheless, the figures show a significant growth of the production, as well as a trend towards a silicon oversupply situation, for the next two to three years.

The announced production capacities – based on a survey of more than 300 companies world-wide – increased despite difficult economic conditions. Although a significant number of players announced a scale-back or cancellation of their expansion plans for the time being, the number of new entrants into the field, notably large semiconductor or energy-related companies, overcompensated this. At least on paper the expected production capacities are increasing. Only published announcements of the respective companies or their representatives and no third source info were used. The cut-off date of the used info was June 2010.

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.

It is important to note that production capacities are often announced, taking into account different operation models such as number of shifts, operating hours per year, etc. In addition, the announcements of the increase in production capacity do not always specify when the capacity will be fully ramped up and operational. 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 the scale-back of expansion plans are often delayed in order not to upset financial markets. In addition, the assessment of all the capacity increases is further complicated by the fact that announcements of the increase in production capacity often lack the information about completion date. Therefore, the capacity figures just give a trend, but do not represent final numbers.

If all these ambitious plans can be realised by 2015, China will have about 34.7 % of the world-wide production capacity of 70 GW, followed by Taiwan (15.9 %), Europe (14.6 %) and Japan (13.1 %) (Fig. 6).

All these ambitious plans to increase production capacities at such a rapid pace depend on the expectations that markets will grow accordingly. This, however, is the biggest uncertainty as the market estimates for 2010 vary between 9 GW and 24 GW with a consensus value in the 13 GW range. In addition, most markets are still dependent on public support in the form of feed-in tariffs, investment subsidies or tax-breaks.

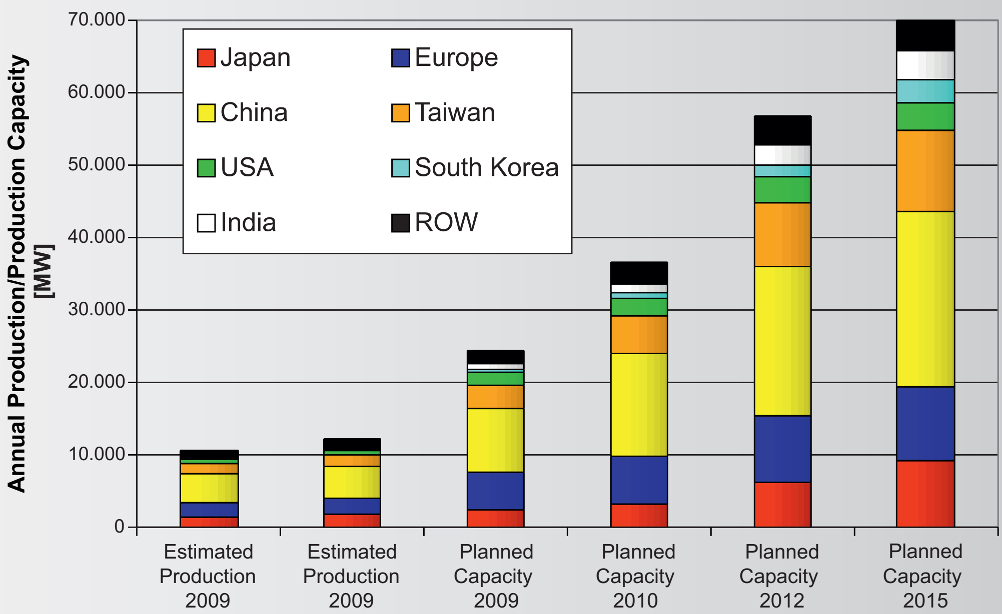
Already now, electricity production from photovoltaic solar systems has shown that it can be cheaper than peak prices in the electricity exchange. In the first half of 2010, solar photovoltaic electricity system prices below € 2,500 per kWp for small residential systems (up to 5 kWp) were a reality. With such investment costs, the electricity generation costs are already at the level of residential electricity prices in some countries, depending on the actual electricity price and the local solar radiation level. But only if markets and competition will continue to grow, prices of the photovoltaic systems will continue to decrease and make electricity from PV systems for consumers even cheaper than from conventional sources. In order to achieve the price reductions and reach grid-parity for electricity generated from photovoltaic systems, public support, especially on regulatory measures, will be necessary for the next decade.

3.1 Technology Mix

Wafer-based silicon solar cells is still the main technology and had around 80 % market shares in 2009. Polycrystalline solar cells still dominate the market (45 to 50 %), even if the market share has slightly decreased since the beginning of the decade. Commercial module efficiencies are within a wide range between 12 and 20 %, with monocrystalline modules between 14 % – 20 %, and polycrystalline modules between 12 % – 17 %. The massive manufacturing capacity increases for both technologies are followed by the necessary capacity expansions for polysilicon raw material.

In 2005, production of thin-film solar modules reached for the first time more than 100 MW per annum. Since then,

Fig. 6: World-wide PV Production 2009 with future planned production capacity increases



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 16 – 20 % in 2009.

More than 200 companies are involved in thin-film solar cell activities, ranging from basic R&D activities to major manufacturing activities and over 150 of them have announced the start or increase of production. The first 100 MW thin-film factories became operational in 2007. If all expansion plans are realised in time, thin-film pro duction capacity could be 20.0 GW, or 35 % of the total 56.7 GW, in 2012 and 23.5 GW, or 34 %, in 2015 of a total of 70 GW (Fig. 7). The first thin-film factories with GW production capacity are already under construction for various thin-film technologies.

One should bear in mind that only one fourth of the over 150 companies with announced production plans have already produced thin-film modules on a commercial scale in 2009.

More than 100 companies are silicon based and use either amorphous silicon or an amorphous/microcrystalline silicon structure. 30 companies announced using Cu(In,Ga)(Se,S)2 as absorber material for their thin-film solar modules, whereas 9 companies use CdTe and 8 companies go for dye and other materials.

[14] High concentration > 300 suns (HCPV), medium concentration 5 < x < 300 suns (MCPV), low concentration < 5 suns (LCPV) .

Concentrating Photovoltaics (CPV) is an emerging technology which is growing at a very high pace, although from a low starting point. About 50 companies are active in the field of CPV development and almost 60 % of them were founded in the last five years. Over half of the companies are located either in the United States of America (primarily in California) and Europe (primarily in Spain).

Within CPV there is a differentiation according the concentration factors[14] and whether the system uses a dish (Dish CPV) or lenses (lens CPV). The main parts of a CPV system are the cells, the optical elements and the tracking devices. The recent growth in CPV is based on significant improvements in all of these areas, as well as the system integration. However, it should be pointed out that CPV is just at the beginning of an industry learning curve with a considerable potential for technical and cost improvements. The most challenging task is to become cost competitive with other PV technologies quickly enough in order to use the window of opportunities for growth.

With market estimates for 2009 in the 20 to 30 MW range, the market share of CPV is still small, but already for 2010 about 100 MW are expected and there is a wide consensus amongst consultancies and market analysts that CPV will reach a GW market size by 2013.

The existing photovoltaic technology mix is a solid foundation for future growth of the sector as a whole. No single

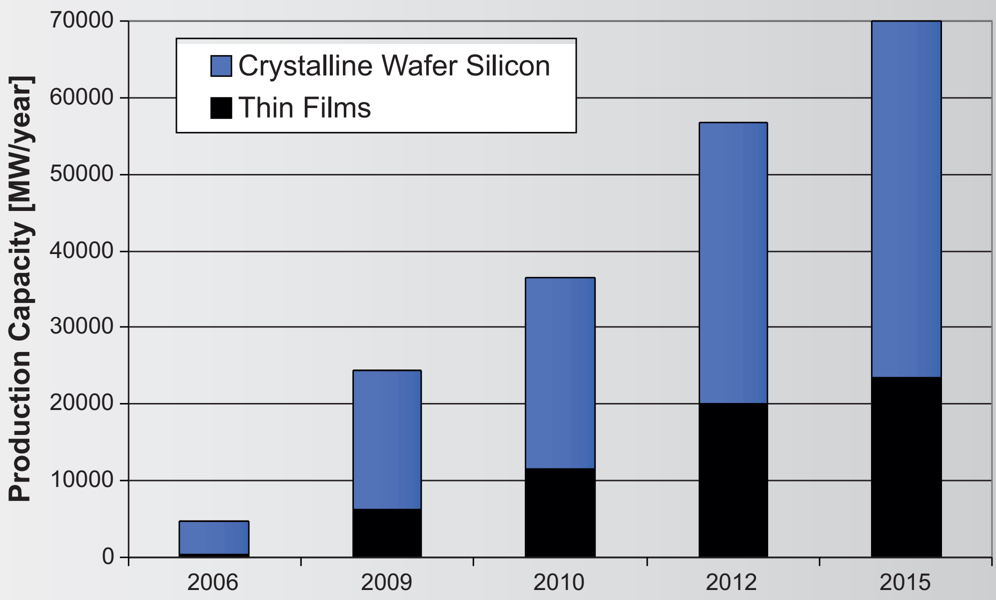


Fig. 7: Annual PV Production capacities of Thin-Film and Crystalline Silicon based solar modules.

technology can satisfy all the different consumer needs, ranging from mobile and consumer applications with the need for a few watts to multi MW utility-scale power plants. The variety of technologies is an insurance against a roadblock for the implementation of solar photovoltaic electricity if material limitations or technical obstacles restrict the further growth or development of a single technology pathway.

3.2 Solar Cell Production[15] Companies

World-wide more than 300 companies produce solar cells. The following chapter gives a short description of the 20 largest companies, in terms of expected production capacity in 2010. More information about additional solar cell companies and details can be found in various market studies and in the country chapters of this report. The capacity, production or shipment data are from the annual reports or financial statements of the respective companies or the cited references.

3.2.1 Suntech Power Co. Ltd. (PRC)

Suntech Power Co. Ltd. (www.suntech-power.com) 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 2009, Suntech reported shipments of 704 MW and held 2rd place in the Top-10 list. 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. The annual production capacity of Suntech Power was increased to 1 GW by the end of 2008 and the company plans to expand their capacity to 1.4 GW in 2010.

3.2.2 First Solar LLC. (USA)

First Solar LLC (http://www.firstsolar.com) 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 through-put 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. 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 1.335 GW at the end of 2010. Further expansions are under way in Kulim and a doubling of the capacity of the Frankfurt plant in 2011 was announced in June 2010. A new factory in the framework of a joint venture with EdF Nuovelles in France with at least 100 MW capacity is planned for 2011. In 2009 the company produced 1,112 MW and currently sets the production cost benchmark with 0.81 $/Wp (0.62 €/Wp) in the first quarter of 2010.

3.2.3 Sharp Corporation (Japan)

Sharp (www.sharp-world.com) started to develop solar cells in 1959 and commercial production got under way 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. Sharp aims to become a "Zero Global Warming Impact Company by 2010" as the World's Top Manufacturer of Solar Cells.

In 2009 Sharp had a production capacity of 855 MWp/year and produced 595 MW [Pvn 2010, Ikk 2010]. Sharp has two solar cell factories at the Katsuragi, Nara Prefecture (695 MW c-Si and 160 MW a-Si their triple-junction thin-film solar cell) and Oska (the 160 MW a-Si their triple-junction thin-film solar cell in spring 2010 are to be expanded to 480 MW by the end of 2010), five module factories and the Toyama factory to recycle and 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. The companies also signed an MoU to set up a manufacturing plant with an initial capacity of 480 MW.

3.2.4 Q-Cells AG (Germany)

Q-Cells SE (http://www.qcells.de) 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 2009 Annual Report, the company stated that the nominal capacity was 800 MW by end of 2009 and the production of the 600 MW factory in Malay-

[15] 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.

sia should reach full capacity during 2010 increasing the total capacity to 1.1 GW. 2009 production was 537 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 solar cell manufacturing subsidiaries, Solibro (CIGS), Calylyxo GmbH (CdTe) (93 %), Flexcell, Switzerland (54.2 %), two joint ventures Sovello (former EverQ; 33.33 %) and Sunfilm AG (50 %), as well as holdings in Solaria Corp., USA (26.6 %).

3.2.5 JA Solar Holding Co. Ltd. (PRC)
JingAo Solar Co. Ltd. (http://www.jasolar.com) 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 875 MW at the end of 2009 to 1,100 MW in 2010. For 2009 the company reported shipments of 509 MW.

3.2.6 Yingli Green Energy Holding Company Ltd. (PRC)
Yingli Green Energy (http://www.yinglisolar.com/) 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. According to the company, production capacity was 600 MW at the end of 2009. In 2010 a further expansion to 1 GW is under construction and should be finished by the end of the year. The financial statement for 2009 gave shipments of 525 MW.

In January 2010, the Ministry of Science and Technology of China approved the application to establish a national-level key laboratory in the field of PV technology development, the State Key Laboratory of PV Technology at Yingli Green Energy's manufacturing base in Baoding.

3.2.7 Trina Solar Ltd, PRC (PRC)
Trina Solar (http://www.trinasolar.com/) 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 600 MW for each of ingot, wafer, cell and modules at the end of 2009 and it is planned to expand the capacities to 900 MW in 2010. For 2009, shipments of 399 MW were reported.

In January 2010, the company announced that it was selected by the Chinese Ministry of Science and Technology to establish a State Key Laboratory to develop PV technologies within the Changzhou Trina PV Industrial Park. The laboratory is established as a national platform for driving PV technologies in China. Its mandate includes research into PV-related materials, cell and module technologies and system-level performance. It will also serve as a platform to bring together technical capabilities from the company's strategic partners, including customers and key PV component suppliers, as well as universities and research institutions.

3.2.8 Motech Solar (Taiwan)
Motech Solar (http://www.motech.com.tw) 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 360 MW in 2009. Production capacity should increase from 600 MW at the end of 2009 to 800 MW in 2010. 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.

At the end of 2009, the company announced that it acquired the module manufacturing facilities of GE in Delaware, USA.

3.2.9 Neo Solar Power Corporation (Taiwan)
Neo Solar Power (http://www.neosolarpower.com/) was founded in 2005 by PowerChip Semiconductor, Taiwan's largest DRAM company, and went public in October 2007. The company manufactures mono- and multicrystalline silicon solar cells and offers their SUPERCELL multicrystalline solar-cell brand with 16.8 % efficiency. Production capacity of silicon solar cells at the end of 2009 was 240 MW and the expansion to 800 MW should be compleded in the fourth quarter 2010. In 2008 the company had shipments of 201 MW.

3.2.10 Gintech Energy Corporation (Taiwan)

Gintech (http://www.gintech.com.tw/) was established in August 2005 and went public in December 2006. Production at Factory Site A, Hsinchu Science Park, began in 2007 with an initial production capacity of 260MW and has increased to 640MW at the end of 2009. The company plans to expand capacity to 750 MW in 2010 and to 1.5 GW by 2011. In 2009 the company had a production of 400 MW [Pvn 2010].

3.2.11 Renewable Energy Corporation AS (Norway)

REC's (http://www.recgroup.com/) 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.

REC ScanCell is located in Narvik, producing solar cells. From the start-up in 2003, the factory has been continuously expanding. In 2009, production of solar cells was 140 MW with a capacity at year end of 180 MWp in Norway and 100 MW in Singapore. Further expansion is under way in Singapore with the ramp-up to full capacity of 550 MW planned for 2010.

3.2.12 Canadian Solar Inc. (PRC)

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, solar cells and solar modules. According to the company, it achieved 120-150 MW of ingot and wafer capacity in 2008 and plans to increase it to 350 MW by the end of 2010. Solar cell capacity was 420 MW at the end of 2009 and the expansion to 700 MW will be operational in June 2010. The module capacity was increased from 820 MW to 1 GW in April 2010. For 2009 the company reported shipments of 325 MW.

3.2.13 SunPower Corporation (USA)

SunPower (http://us.sunpowercorp.com/) 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 Manila in the Philippines. Fab. No 1 has a nameplate capacity of 108 MW and Fab. No 2 adds another nameplate capacity of 466 MW. Fab. No 3, a joint venture with AU Optronics Corporation (AUO), with a planned capacity of 1.4 GW is currently under construction in Malaysia. Production in 2009 was reported at 397 MW.

3.2.14 Solar World AG (Germany)

Since its founding in 1998, Solar World (http://www.solarworld.de/) has changed from a solar system and components dealer to a company covering the whole PV value chain from wafer production to system installations. The company now has manufacturing operations for silicon wafers, cells and modules in Freiberg, Germany and Hillsoboro (OR), USA. Additional solar module production facilities exist in Camarillo (CA), USA and since 2008 with a joint venture between Solarworld and SolarPark Engineering Co. Ltd. in Jeonju, South Korea.

For 2009, solar cell production capacities in Germany were reported at 200 MW and 250 MW in the USA. For 2010 an expansion to 250 MW in Germany and 375 MW in the USA are planned. Total cell production in 2009 was 252 MW with 180 MW coming from Germany and 72 MW form the USA.

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.

3.2.15 Kyocera Corporation (Japan)

In 1975 Kyocera (http://global.kyocera.com/prdct/solar/) 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 started as the first Japanese company to sell home PV generation systems.

Besides the solar cell manufacturing plants in Japan, Kyocera has module manufacturing plants in China (joint venture with the Tianjin Yiqing Group (10 % share) in Tianjin since 2003), Tijuana, Mexico (since 2004) and in Kadan, Czech Republic (since 2005).

In 2009, Kyocera had a production of 400 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 solar companies, Kyocera is planning to increase its current capacity of 350 MW to 600 MW in 2010 and 1 GW by 2012.

3.2.16 SANYO Electric Company (Japan)
Sanyo (http://sanyo.com/solar/) 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 2009 Sanyo produced 260 MW solar cells [Pvn 2010]. The company announced to increase its 2009 production capacity of 500 MW HIT cells to 650 MW by 2011.

At the end of 2002, Sanyo announced the start of module production outside Japan. The company now has a HIT PV module production 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.

Sanyo has set a world record for the efficiency of the HIT solar cell with 23 % under laboratory conditions [Tag 2009]. The HIT structure offers the possibility to produce double-sided solar cells, which offer the advantage of collecting 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.

3.2.17 E-TON Solartech Co. Ltd. (Taiwan)
E-Ton Solartech (http://www.e-tonsolar.com) was founded in 2001 by the E-Ton Group, a multi-national conglomerate dedicated to producing sustainable technology and energy solutions and was listed on the Taiwan OTC stock exchange in 2006.

At the end of 2009 the production capacity was 440 MW per annum and a capacity increase to 560 MW is foreseen for 2010. Shipments of solar cells were reported at 225 MW for 2009.

3.2.18 NingBo Solar Electric Power Co. Ltd. (PRC)
NingBo Solar (http://www.nbsolar.com/) or Sun-Erath has been part of China's PuTian Group since 2003. The company has four main facilities for silicon production, ingot manufacturing, system integration and solar system production. According to company information Ningbo has imported solar cell and module producing and assembling lines from America and Japan.

In 2007, Ningbo Solar relocated to the Ningbo high-tech zone, with the global headquarters of Ningbo Solar. There, the company produces wafers, solar cells and solar modules. The second phase of production capacity expansion to 350 MW was completed in 2009. Further expansion is planned to 500 MW in 2010, 800 MW in 2011 and 1 GW in 2012. For 2009 shipments of 260 MW were reported [Pvn 2010].

3.2.19 Solarfun Power Holdings (PRC)
Solarfun (http://www.solarfun-power.com/) was established in 2004 by the electricity metre manufacturer Lingyang Electronics, the largest Chinese manufacturer of electric power meters. The company produces silicon ingots, wafers, solar cells and solar modules. 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. The capacity expansion to 500 MW will be completed in June 2010. For 2009, solar cell production of 300 MW was reported [Pvn 2010].

3.2.20 Bosch Solar (Germany)
The Bosch Group, a leading global supplier of technology and services in the areas of automotive and industrial technology, consumer goods, and building technology, took over the 1997 founded ErSol Solar Energy AG Erfurt in 2008 and renamed it Bosh Solar (http://www.bosch-solarenergy.de/). Bosh Solar manufactures and distributes photovoltaic crystalline and thin-film silicon products. In 2009 the company had a production of 200 MW [Pvn 2010] and a production capacity of 280 MW wafers, 280 MW crystalline solar cells and 40 MW thin-films at the end of 2009. Further expansion to 830 MW (630 MW Si-cells and 200 MW thin-films) is planned.

Bosh Solar holds a 35 % interest in 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 has been producing solar mod ules since 2006. In 2009 Bosch Solar also acquired 68.7 % of the German module manufacturer Aleo Solar AG and took over the majority of the German CIS company Johanna Solar GmbH.

3.3. Polysilicon supply

The rapid growth of the PV industry since 2000 led to the situation where, between 2004 and early 2008, the demand for polysilicon outstripped the supply from the semiconductor industry. Prices for purified silicon started to rise sharply in 2007 and in 2008 prices for ***polysilicon*** peaked around 500 $/kg and consequently resulted in higher prices for PV modules. This extreme price hike triggered a massive capacity expansion, not only of established companies, but many new entrants as well. In 2009 more than ninety percent of total polysilicon for the semiconductor and photovoltaic industry was supplied by seven companies: Hemlock, Wacker Chemie, REC, Tokuyama, MEMC, Mitsubishi and Sumitomo. However, it is estimated that now about seventy producers are present in the market.

The massive production expansions, as well as the difficult economic situation, led to a price decrease throughout 2009 reaching about 50–55 $/kg on average by year's end. Prices are expected to continue to drop over the next three years, but at a much slower rate levelling in the 40 to 50 $/kg range in 2012.

For 2009, about 88,000 metric tons of solar grade silicon production were reported, sufficient for around 11 GW under the assumption of an average materials need of 8 g/Wp [Dis 2010]. China produced about 18,000 metric tons, or 20 %, fulfilling about half of the domestic demand [Bao 2010]. According to the Chinese Ministry of Industry and Information Technology, about 44,000 metric tons of polysilicon production capacity was reached with a further 68,000 metric tons capacity under construction in 2009.

Projected silicon production capacities available for solar in 2012 vary between 140,000 metric tons from established polysilicon producers, up to 185,000 metric tons including the new producers [Hom 2009] and 250,000 metric tons [Ber 2010]. The possible solar cell production will in addition depend on the material use per Wp. Material consumption could decrease from the current 8 g/Wp to 7 g/Wp, or even 6 g/Wp, but this might not be achieved by all manufacturers.

3.3.1 Silicon production processes

The high growth rates of the photovoltaic industry and the market dynamics forced the high-purity silicon companies to explore process improvements, mainly for two chemical vapour deposition (CVD) approaches — an established production approach known as the Siemens process, and a manufacturing scheme based on fluidised bed (FB) reactors. Improved versions of these two types of processes will very probably be the work-horses of the polysilicon production industry for the near future.

Siemens process – In the late 1950s the Siemens reactor was developed and has been the dominant production route since. About 80 % of total polysilicon manufactured world-wide was made with a Siemens-type process in 2009. The Siemens process involves deposition of silicon from a mixture of purified silane or trichlorosilane gas with an excess of hydrogen onto high-purity polysilicon filaments. The silicon growth then occurs inside an insulated reaction chamber or “bell jar”, which contains the gases. The filaments are assembled as electric circuits in series and are heated to the vapour deposition temperature by an external direct current. The silicon filaments are heated to very high temperatures between 1,100 – 1,175 °C at which trichlorsilane, with the help of the hydrogen decomposes to elemental silicon and deposits as a thin-layer film onto the filaments. Hydrogen Chloride (HCl) is formed as a by-product.

The most critical process parameter is temperature control. The temperature of the gas and filaments must be high enough for the silicon from the gas to deposit onto the solid surface of the filament, but well below the melting point of 1,414 °C, that the filaments do not start to melt. Second, the deposition rate must be well controlled and not too fast because otherwise the silicon will not deposit in a uniform, polycrystalline manner, making the material unsuitable for semiconductor and solar applications.

Fluidised bed process – A number of companies develop polysilicon production processes based on fluidised bed (FB) reactors. The motivation to use the FB approach is the potentially lower energy consumption and a continuous production, compared to the Siemens batch process.
In this process, tetrahydrosilane or trichlorosilane and hydrogen gases are continuously introduced onto the bottom of the FB reactor at moderately elevated temperatures and pressures. At a continuous rate high-purity silicon seeds are inserted from the top and are suspended by the upward flow of gases. At the operating temperatures of 750 °C, the silane gas is reduced to elemental silicon and deposits on the surface of the silicon seeds. The growing seed crystals fall to the bottom of the reactor where they are continuously removed.

MEMC Electronic Materials, a silicon wafer manufacturer, has been producing granular silicon from silane feedstock using a fluidised bed approach for over a decade. Several new facilities will also feature variations of the FB. Several major players in the polysilicon industry, including Wacker Chemie and Hemlock, are developing FB processes, while at the same time continuing to produce silicon using the Siemens process as well.

Upgraded metallurgical grade (UMG) silicon was seen as one option to produce cheaper solar grade silicon with 5- or 6-nines purity, but the support for this technology is waning in an environment where higher-purity methods are cost-competitive. A number of companies delayed or suspended their UMG-silicon operations as a result of low prices and lack of demand for UMG material for solar cells.

3.4 Polysilicon Manufacturers

World-wide more than 100 companies produce or start up polysilicon production. The following chapter gives a short description of the 10 largest companies in terms of expected production capacity in 2010. More information about additional polisilicon companies and details can be found in various market studies and the country chapters of this report.

3.4.1 Hemlock Semiconductor Corporation (USA)

Hemlock Semiconductor Corporation (http://www.hscpoly.com) 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. In 2009 19,000 tons of production were reported [Ene 2010].

3.4.2 Wacker Polysilicon (Germany)

Wacker Polysilicon AG (http://www.wacker.com), is one of the world's leading manufacturers of hyper-pure polysilicon for the semiconductor and photovoltaic industry, chlorosilanes and fumed silica. In 2009, Wacker increased its capacity to approximately 20,000 tons and produced 18,100 tons of polysilicon. The next 10,000 tons expansion stage became operational in April 2010 and another 10,000 tons expansion is under construction in Nünchritz (Saxony), Germany, which is scheduled to start up in 2011. Early 2010, the company received tax credits from the US Recovery Fund for their planned polysilicon plant in Tennessee, which is scheduled to start operation in 2013.

3.4.3 OCI Company (South Korea)

OCI Company Ltd. (formerly DC Chemical) (http://www.oci.co.kr/) is a global chemical company with a product portfolio spanning the fields of inorganic chemicals, petro and coal chemicals, fine chemicals, and renewable energy materials. In 2006 the company started their polysilicon business and successfully completed their 6,500 metric ton P1 plant in December 2007. The 10,500 metric ton P2 expansion was completed in July 2009. A further 10,000 metric ton capacity expansion is under construction and will bring the total capacity to 27,000 metric tons once completed at the end of 2010. For 2009 a silicon production of 6,500 tons was reported [Ene 2010].

3.4.4 GCL-Poly Energy Holdings Limited (PRC)

GCL-Poly (http://www.gcl-poly.com.hk) 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 an 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, was reached at the end of 2009. A further expansion to 24,000 tons is planned to be finished in 2010. For 2009 the company reported a production 7,450 metric tons of polysilicon.

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.

3.4.5 MEMC Electronic Materials Inc. (USA)

MEMC Electronic Materials Inc. (http://www.memc.com/) 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 Tetraflouride (SiF4), Sodium Aluminum Tetraflouride (SAF). MEMC's production capacity in 2008 was increased to 8000 tons and the company plans to increase capacity further to 15,000 tons in 2010. For 2009 10,000 tons of production were reported [Ene 2010].

3.4.6 Renewable Energy Corporation AS (Norway)

REC's (http://www.recgroup.com/) 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). The company is expanding the Moses Plant by adding 10,500 tons of new capacity. Plant III (6,500 tons) was ramped-up in 2009 and plant IV (4,000 tons) is planned to be ramped-up in the first half of 2010, bringing total capacity to about 13,500 tons. According to the company, about 8,100 tons were produced in 2009 and the production outlook for 2010 was revised to 12,000 tons.

3.4.7 LDK Solar Co. Ltd. (PRC)

LDK (http://www.ldksolar.com/) was set up by the Liouxin Group, a company which manufactures 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. In 2008 the company announced that they completed the construction and commenced polysilicon production in their 1,000 metric tons polysilicon plant. Further expansion with a 15,000 metric ton plant in three 5,000 phases is underway and the company announced the completion of the second phase in May 2010, bringing the total capacity to 11,000 metric tons. In 2009 polysilicon production was in the range of 1,000 tons.

3.4.8 Tokuyama Corporation (Japan)

Tokuyama (http://www.tokuyama.co.jp/) 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. 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. For 2009, silicon production of 8,200 tons was reported [Ene 2010].

Tokuyama has decided to form a joint venture with Mitsui Chemicals, a leading supplier of silane gas. 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.

3.4.9 Elkem AS (Norway)

Elkem (http://www.elkem.com) is a subsidiary of Orkla ASA, and one of Norway's largest industrial companies and the world's largest producer of silicon metal. Elkem Solar developed a 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 has a capacity of 6,000 tons of solar grade silicon and was opened in 2009.

3.4.10 Mitsubishi Materials Corporation (Japan)

Mitsubishi Materials (http://www.mmc.co.jp) was created through the merger Mitsubishi Metal and Mitsubishi Mining & Cement in 1990. Polysilicon production is one of the activities in their Electronic Materials & Components business unit. The company has two production sites for polysilicon, one in Japan and one in the USA (Mitsubishi Polycrystalline Silicon America Corporation) and is a shareholder (12.25 %) in Hemlock Semiconductor Corporation. With the expansion of the Yokkachi, Mie, Japan, polysilicon plant by 1,000 tons in 2010, total production capacity increases to 4,300 tons.

4. The European Union

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]. The 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 CO_2-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 2009 was 16 GW, more than 5 times the original target.

As depicted in Figure 8, the overall progress of the European Union towards the 2010 targets is very positive with 18.2 % of the Union's total net electricity generation coming from renewable energy sources. However, it should be noted that this development is still short of the 21 % needed and that the electricity demand in 2009 has decreased by 5 % compared to 2008 due to the economic crisis. In addition, the development in the different Member States is quite diverse as nine Member States have exceeded their targets, whereas some others are lagging behind.

The 2009 Directive indicates the overall percentage of renewable energies for the different Member States (Fig. 9) as well as the indicative trajectory (Fig. 10) 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 had to notify the Commission about their National Renewable Energy Action Plans (NRAPs). As stated in the Directive, the aim of these plans is *that all Member States, including those which so far have made very limited progress towards agreed EU objectives, will have to establish a clear plan as to how they intend to achieve their targets for renewable energy and for renewable energy in transport. They will have to explain how they intend to reform building codes and planning regimes to increase the use of renewable energy and to improve access conditions to the electricity grid. They will have to set out national sectoral targets, the measures and support schemes to be used to reach the targets, the specific measures for the promotion of the use of energy from biomass, the intended use of (statistical) transfers of renewable energy from other Member States and their assessment of the role different technologies will play in reaching the targets. Moreover they will have to implement and monitor biofuel sustainability criteria to ensure biofuels clearly contribute to our environmental objectives.*

Fig. 8: Electricity generation in TWh from renewable energies in the European Union [Est 2010, a]

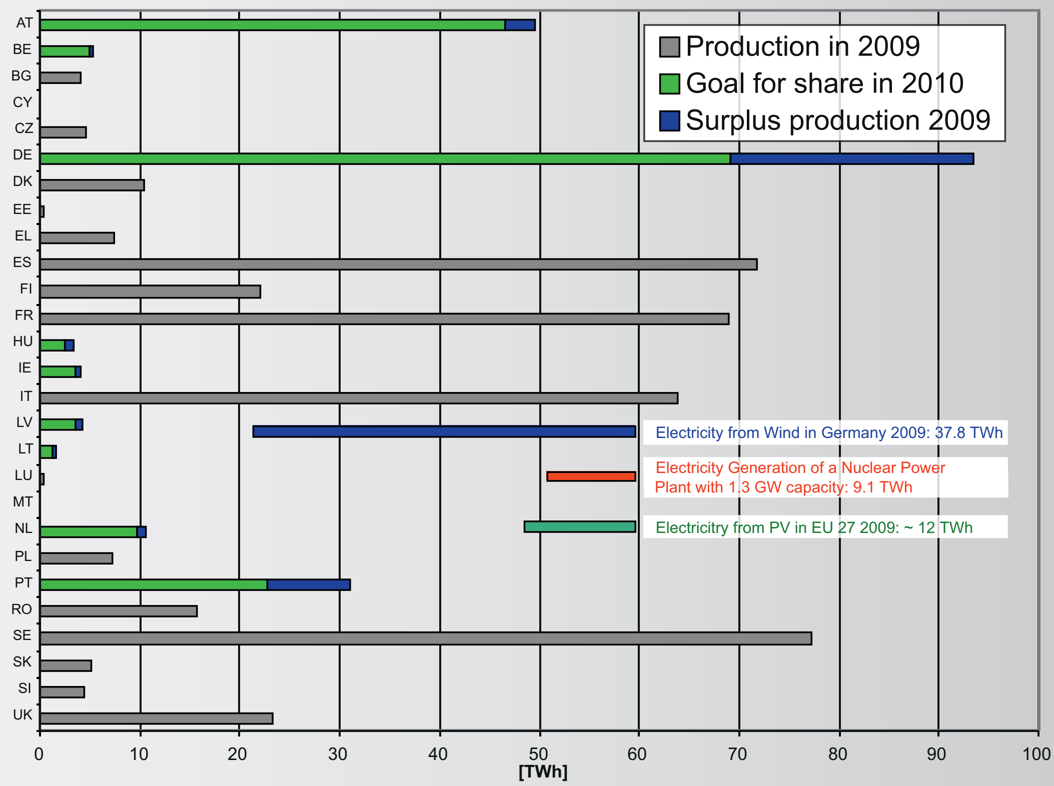


Fig. 9: Share of renewable energies in the European Union in 2020

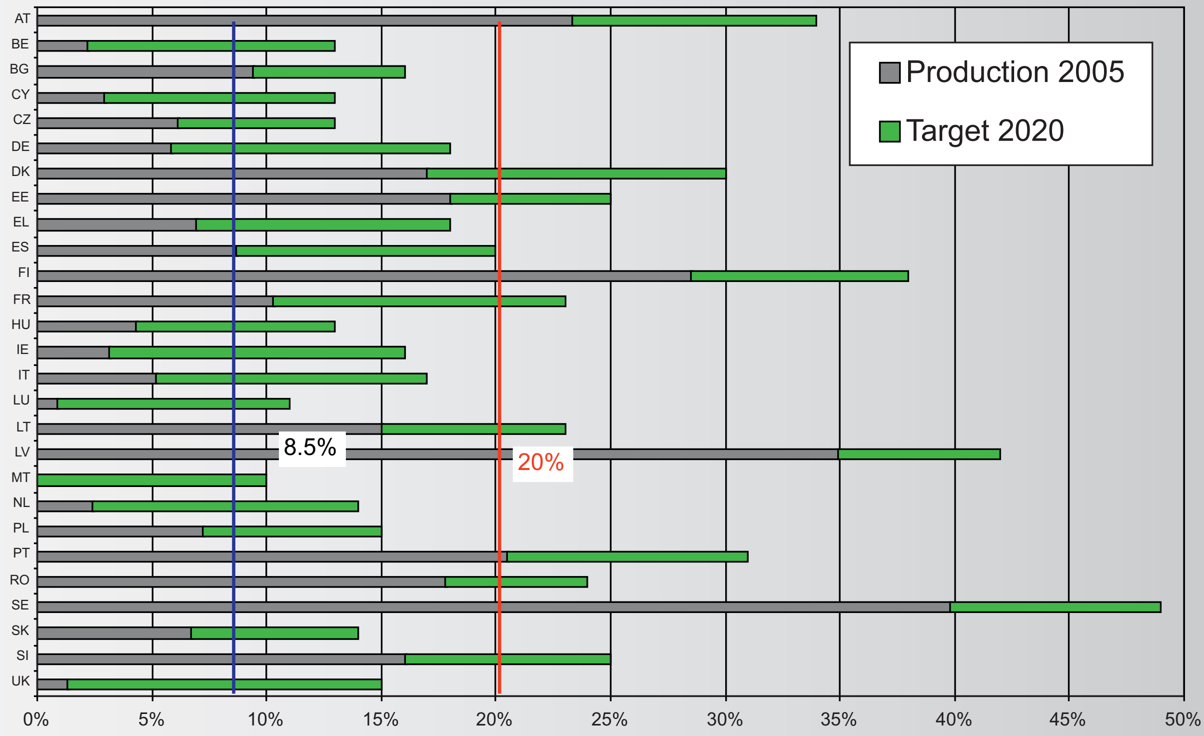
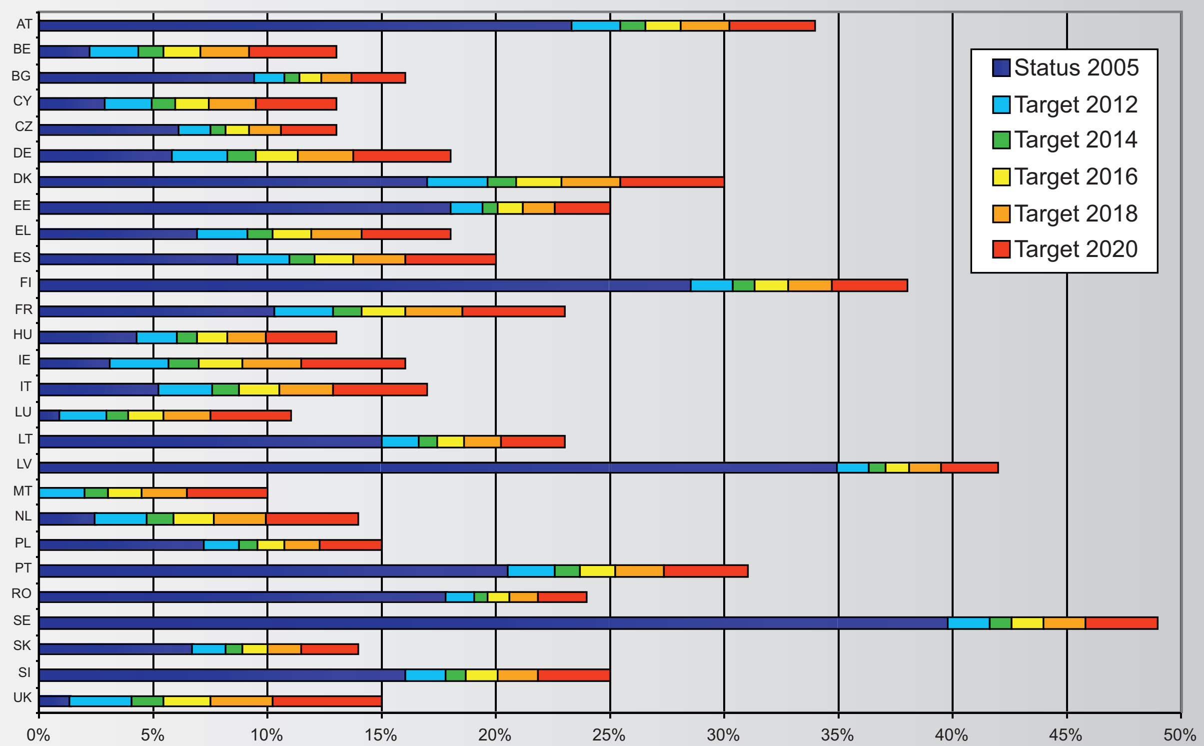


Fig. 10: Trajectory to reach the share of renewable energies in the European Union in 2020



4.1 Implementation of Photovoltaics 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. The legal framework for the overall increase of renewable energy sources was set with the Directive 2009/28/EC, but so far only 5 Member States have indicated specific photovoltaic solar energy targets. Not only is this a minority of the Member States, but the indicated target of 25.74 GW (10 GW Spain, 8 GW Italy, 5.4 GW France, 1.5 GW Portugal and 0.84 GW Greece) is far below (factor 2 to 6) the anticipated contribution of these sun-rich countries in order to reach 6% of solar electricity by 2020, where a cumulative installed capacity of about 200 GW in Europe would be needed [Epi 2009].

The tremendous growth of the European PV Market to 5.8 GW in 2009 did not result in a similar growth of the European PV production, which reached about 2 GW. 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 dominating support measures for photovoltaics in the European Union Member States and Switzerland are feed-in tariffs. The rapid decrease of photovoltaic system prices led to a number of sometimes drastic revisions in the feed-in schemes. The existing support schemes are listed in Table 1.

Table 1: Support mechanisms for photovoltaics in the European Union and Switzerland

Austria	The Ökostromverordnung 2010 (eco electricity degree) set the following new tariffs for 2010 (only for PV systems covered by the Ökostromgesetz (Eco Electricty Law). Systems on buildings or noise barriers: ■ System size between 5 and 20 kWp: 0.38 €/kWh ■ System size > 20 kWp: 0.33 €/kWh Free-standing systems: ■ System size between 5 and 20 kWp: 0.35 €/kWh ■ System size > 20 kWp: 0.25 €/kWh For systems smaller than 5 kWp, the Climate & Energy Fund, which has i n 2010 a budget of € 35 million, offered an investment subsidy to private persons. Applications on a first come first serve base were possible between 28 June and 31 August 2010. For 2010 the investment subsidies were as follows: ■ Roof-top and free standing systems: 1,300 €/kWp ■ Building integrated system: 1,700 €/kWp Some of the Federal States have additional investment support schemes.

Belgium

Green Certificates (with guaranteed minimum price):

- Brussels: 0.15 – 0.65 €/kWh depending on size (10 years)
- Wallonia: 0.15 – 0.70 €/kWh depending on size and actual GC value (15 years)
- Flanders
  from 1 January 2010: 0.35 €/kWh and
  from 1 January 2011: 0.33 €/kWh for 20 years.

Net meeting possible for systems smaller than 10 kWp

Tax reduction available

Bulgaria

In November 2008 the duration of FIT payments was changed from 12 to 25 years and from 1 April 2009 on only systems with a capacity of a maximum of 10 MW are eligible for the tariff. The tariffs for 2010 were set by the regulator on 31 March 2010:

- 0.793 BGN/kWh (0.405 €/kWh)[16] for systems up to 5 kW
- 0.728 BGN/kWh (0.372 €/kWh) for systems < 5 kW and ≤ 10 MW

Up to 15 %, or a maximum of € 2.5 million of the project investment, can be financed with a reduced interest loan from the Bulgarian Energy Efficiency and Renewable Energy Credit Line (BEERECL), credit facility offered by the European Bank for Reconstruction and Development (EBRD), the Bulgarian Government and the European Union.

[16] Exchange rate: 1 € = 1.956 BGN

Cyprus

Investment grants for households, other entities and organisations not engaged in economic activities are limited to a maximum of 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

- 0.224CYP£/kWh (0.415 €/kWh)[17] for households
- 0.196CYP£/kWh (0.363 €/kWh) for enterprises

With investment subsidy

- 0.12CYP£/kWh (0.222 €/kWh)

[17] 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 2010:
  Systems commissioned after 01/01/10:
  ≤ 30 kW: 12.25 CZK/kWh (0.474 €/kWh)[18]
  > 30 kW: 12.15 CZK/kWh (0. 460 €/kWh

- Market price + Green Bonus; Green Bonus 2010
  Systems commissioned after 01/01/10:
  ≤ 30 kW: 11.28 CZK/kWh (0.436 €/kWh)
  > 30 kW: 11.18 CZK/kWh (0.433 €/kWh

Income is exempt from taxes (Act No. 589/1992 on income tax), VAT reduction from 19 % to 9 %.

Operators may receive subsidies under the European Structural Funds or national programmes.

[18] Exchange rate: 1 € = 25.84 CZK

Denmark

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 [19].

[19] Exchange Rate: 1 € = 7.45 DKK

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) for systems with start of operation 2007 – 2009 [20].
- 0.85 EEK/kWh (0.054 €/kWh) for systems with start of operation 2010 and after.

[20] 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

In January 2010 the tariffs were changed as follows:
BIPV (dwellings and health care): 0.58 €/kWh up from 0.52 €/kWh
BIPV (other buildings): 0.50 €/kWh up from 0.45 €/kWh
Simplified BIPV: 0.42 €/kWh down from 0.52 €/kWh

Ground-mounted PV < 250 kW: 0.314 €/kWh down from 0.32 €/kWh

For roof-top and roof-mounted PV systems >250 kW
a correction coefficient R with respect to the solar radiation was introduced:
0.314 €/kWh * (1 + R) where R varies from 0 to 0.2.

The result varies between
In the sunny south: 0.314 €/kWh down from 0.32 €/kWh
In the cloudy north: 0.377 €/kWh up from 0.32 €/kWh

Roof-top and ground-mounted systems in the overseas regions and Corsica:
0.40 €/kWh down from 0.42 €/kWh

The main additional regulations are:

- Contract duration 20 years, linked to inflation, but the inflation indexing was reduced to 20 %.

- Additional investment subsidies are available as tax credits. 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.

- Starting from 2012, the tariff for new contracts will annually decrease by 10 %.

- Only 1,500 kWh/kWp per year are bought from any fixed installation in the mainland (2,200 kWh/kWp for tracking) at the tariffs listed below. Any surplus will then be bought at 0.05 €/kWh. In Overseas Departments and Corsica, the caps for fixed and tracking installation are respectively 2,200 kWh/kWp and 2,600 kWh/kWp.

Germany

Feed-in tariff for 20 years.

Tariffs for new installations between 1st January and 30th June 2010:
Roof-top

- System size < 30 kW: 0.3914 €/kWh
- System size 30 to 100 kW: 0.3726 €/kWh
- System size 100 kW to 1 MW: 0.3523 €/kWh
- System size > 1 MW: 0.2937 €/kWh

Roof-top with auto consumption:

- System size < 30 kW: 0.2276 €/kWh

Ground-mounted installations: 0.2843 €/kWh

Tariffs for new installations between 1st July to 30th September 2010[20]:
Roof-top

- System size < 30 kW: 0.3405 €/kWh
- System size 30 to 100 kW: 0.3239 €/kWh
- System size 100 kW to 1 MW: 0.3065 €/kWh
- System size > 1 MW: 0.2555 €/kWh

Roof-top with auto consumption:

- System size < 30 kW: first 30 % 0.1767 €/kWh
  remaining 70 % 0.2205 €/kWh
- System size 30 to 100 kW: first 30 % 0.1601 €/kWh
  remaining 70 % 0.2039 €/kWh
- System size 100 to 500 kW: first 30 % 0.1427 €/kWh
  remaining 70 % 0.1865 €/kWh

Ground-mounted installations: 0.2502 €/kWh
Ground-mounted installations in redevelopment areas: 0.2615 €/kWh

Tariffs for new installations between 1st October to 31th December 2010:
Roof-top

- System size < 30 kW: 0.3303 €/kWh
- System size 30 to 100 kW: 0.3142 €/kWh
- System size 100 kW to 1 MW: 0.2973 €/kWh
- System size > 1 MW: 0.2479 €/kWh

Roof-top with auto consumption:

- System size < 30 kW: first 30 % 0.1665 €/kWh
  remaining 70 % 0.2103 €/kWh
- System size 30 to 100 kW: first 30 % 0.1504 €/kWh
  remaining 70 % 0.1942 €/kWh
- System size 100 to 500 kW: first 30 % 0.1335 €/kWh
  remaining 70 % 0.1773 €/kWh

Ground-mounted installations: 0.2426 €/kWh
Ground-mounted installations in redevelopment areas: 0.2537 €/kWh

Germany

The annual degression rate for new systems is as follows:

- System size < 100 kW: 2011 – 9 %
- Sytem size between 100 kW and 1 MW: 2011 – 10 %
- System size > 1 MW and ground-mounted systems: 2011 – 11 %

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. The degression rates will be lowered or increased in the following year if the following installed capacities are undercut or exceeded:

Installations in 2010 and resulting degression in 2011:

- > 3500 MW + 1 % < 2,500 MW – 1 %
- > 4,500 MW + 2 % < 2,000 MW – 2 %
- > 5,500 MW + 3 % < 1,500 MW – 3 %
- > 6,500MW + 4 %

Installations in 2011 and resulting degression in 2012:

- > 3,500 MW + 3 % < 2,500 MW – 2.5 %
- > 4,500 MW + 6 % < 2,000 MW – 5 %
- > 5,500 MW + 9 % < 1,500 MW – 7.5 %
- > 6,500MW + 12.5 %

[21] From 1 July 2010 on no feed-in tariff is paid for new PV systems on agricultural land.

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]:

Start of operation	Mainland Grid		Autonomous island grids	
	> 100 kW_p	≤ 100 kW_p	> 100 kW_p	≤ 100 kW_p
February 2009:	0.40	0.45	0.45	0.50
August 2009:	0.40	0.45	0.45	0.50
February 2010:	0.40	0.45	0.45	0.50
August 2010:	0.392	0.441	0.441	0.49

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).

Greece

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.

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 €[22])

[22] 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].

2010 Tariffs:

Nominal Power	not integrated	partly integrated	building integrated
1 – 3 kW_p	0.3822 €/kWh	0.4214 €/kWh	0.4704 €/kWh
3 – 20 kW_p	0.3626 €/kWh	0.4018 €/kWh	0.4410 €/kWh
> 20 kW_p	0.3430 €/kWh	0.3822 €/kWh	0.4214 €/kWh

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 %

A new *conto energia* with a significant reduction of the tariffs from 2011 on and a more detailed classification of PV systems is under discussion. The main features of the Feediin Tariff Policy for 2011 are:

Italy	1. A 20 % cut in Feed in Tariffs in 2011 to be rolled out in 3 phases with 4 months gap. So apparently a 6.66 % cut in January, May and September. 2. A 30 % cut in FIT for solar plants greater than 5 MW. 3. A 3 GW cap on the installations during this phase with a target of 8 GW by 2020. 4. 6 % cuts in solar subsidy in 2012 and 2013.
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.
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 and a new cap of 5 MW has been set. Tariffs are guaranteed over 15 years with simpler administrative procedures. They are differentiated according to technology and capacity. Some tariffs are degressive. In the case of photovoltaics only roof-top systems are eligible and the tariff is set as follows: ■ System size ≤ 30 kW: 420 x (1-(n-2008) x 3/100) €/MWh (i.e. annual degression rate of 3 %) ■ System size 31 to 1,000 kW: 370 x (1-(n-2008) x 3,00/100) €/MWh In addition, investment subsidies (environmental grants of max 50 % of the investments in the case of self-consumption purposes) are available to private companies. For local authority buildings, investment grants of up to 15 % of the investment cost (max 900 €/kWp) are available. For private households, investment grants up to 30 % of the investment for roof or façade systems up to 30 kWp (max 1,650 €/kWp) are available.

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.

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. The programme has annual caps with a total of 75 MW between 2008 and 2011.

For 2010 the feed-in tariff and caps for for new systems were set as:

- System size 0.6 – 15 kWp: 0.2441 €/kWh 20 MW CAP
- System size 15 – 100 kWp: 0.351 €/kWh 5 MW CAP

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)[23].

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

[23] Exchange rate: 1 € = 4.137 PLN

Portugal

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) is 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 increases by 20 % 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 € 777 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.

Slovakia

Feed-in tariff set by Regulator each year.

The feed-in tariff set in October 2009 is 13.2 SKK/kWh (0.502 €/kWh[24]) guaranteed for 12 years for systems larger than 100 kW, smaller systems receive a premium of 0.3 SKK (0.011 €/kWh).

In addition, PV, like all other RES, qualifies for investment subsidies under the framework of the EU Structural funds.

[24] Exchange rate: 1 € = 26.3 SKK

Slovenia

A revised feed-in tariff scheme went into force in 2009. The main changes were that the guaranteed period changed from 10 to 15 years and that the tariffs were differentiated according to system sizes and type of installations. The tariff was set in 2009 with a 7 % degression per year for new systems from 2010 on.

2010 Tariffs:

Power	roof-top	BIPV	ground-mounted
< 50 kW	0.386 €/kWh	0.444 €/kWh	0.363 €/kWh
< 1 MW	0.353 €/kWh	0.406 €/kWh	0.335 €/kWh
> 1 MW	0.293 €/kWh	0.337 €/kWh	0.270 €/kWh

Each year only 5 MW of new ground-mounted systems can receive the FIT.

Spain

New feed-in tariff with cap of 400 MW + 100 MW (addition for ground based systems) were decided in September 2008, with a provision that two thirds of the 400 MW installations will be on roof-tops. Current tariffs are:

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

A revision with proposed cuts of up to 40 % are currently under discussion.

Sweden

No specific PV programme. Energy tax exemption.

Switzerland

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:

Nominal Power	Ground mounted	Rooftop	Building integrated
		[CHF/kWh (€/kWh)][25]	
< 10 kWp	0.598 (0.427)	0.635 (0.453)	0.828 (0.643)
10 – 30 kWp	0.497 (0.355)	0.598 (0.427)	0.681 (0.486)
30 – 100 kWp	0.469 (0.335)	0.570 (0.407)	0.616 (0.440)
> 100 kWp	0.451 (0.332)	0.552 (0.394)	0.570 (0.407)

[25] Exchange rate: 1 € = 1.40 CHF

United Kingdom

New feed-in tariff was introduced on 1 April 2010 and will be paid for 25 years.

Tariffs:

Power	04/10 – 03/11	04/11 – 03/12	04/12 – 03/13
< 4 kW new buildings	0.361 £/kWh[26]	0.361 £/kWh	0.361 £/kWh
(0.425 €/kWh)	(0.425 €/kWh)	(0.425 €/kWh)	
< 4 kW retrofit	0.413 £/kWh	0.413 £/kWh	0.378 £/kWh
(0.486 €/kWh)	(0.486 €/kWh)	(0.445 €/kWh)	
4 – 10 kW	0.361 £/kWh	0.361 £/kWh	0.330 £/kWh
(0.425 €/kWh)	(0.425 €/kWh)	(0.388 €/kWh)	
10 – 100 kW	0.314 £/kWh	0.314 £/kWh	0.287 £/kWh
(0.369 €/kWh)	(0.369 €/kWh)	(0.338 €/kWh)	
0.1 – 5 MW	0.293 £/kWh	0.293 £/kWh	0.268 £/kWh
(0.345 €/kWh)	(0.345 €/kWh)	(0.315 €/kWh)	
Ground-mounted	0.293 £/kWh	0.293 £/kWh	0.268 £/kWh
(0.345 €/kWh)	(0.345 €/kWh)	(0.315 €/kWh)	

[26] Exchange rate: 1 € = 0.85 GBP

As depicted in Table 1, 21 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,
- not yet established priority grid access for renewable energy sources and photovoltaics 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 [Šúr 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, as well as various industries along the value chain. Especially in Germany, so far the biggest market in Europe, the production capacities for solar cells and modules have increased faster than in other European countries (Fig. 11). It is interesting to note that with the expansion of the Italian, French and Czech markets, also the number of solar manufacturing companies and the supply industry in these countries increased. Only two of the current top-ten European manufacturers hold this position since 2000. The other interesting observation is that the market share of the 10 largest companies is shrinking due to the competition from a large number of new entrants.

Based on information provided by the industry, Greenpeace and EPIA have assumed in their 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 2009. This corresponds quite well with figures reported from 63,000 jobs [Bsw 2010] reported for Germany and 13,900 (11,300 permanent and 2,600 temporary) for Spain [Aso 2010], about 10,000 for Italy [Gfi 2010] and about 6,000 jobs in France [Sol 2010]. It is worthwhile noting that the employment numbers in Spain dropped from over 41,000 in 2008 to 13,900 in 2009 due to the installation cap to 500 MW. For 2010 the direct employment figures in photovoltaics for the European Union are estimated to be in the range of 120,000 to 150,000. If jobs in the equipment manufacturing industry and along the supply chain are added, EPIA estimated about 300,000 European jobs for 2009 and 400,000 jobs for 2010 [Epi 2009].

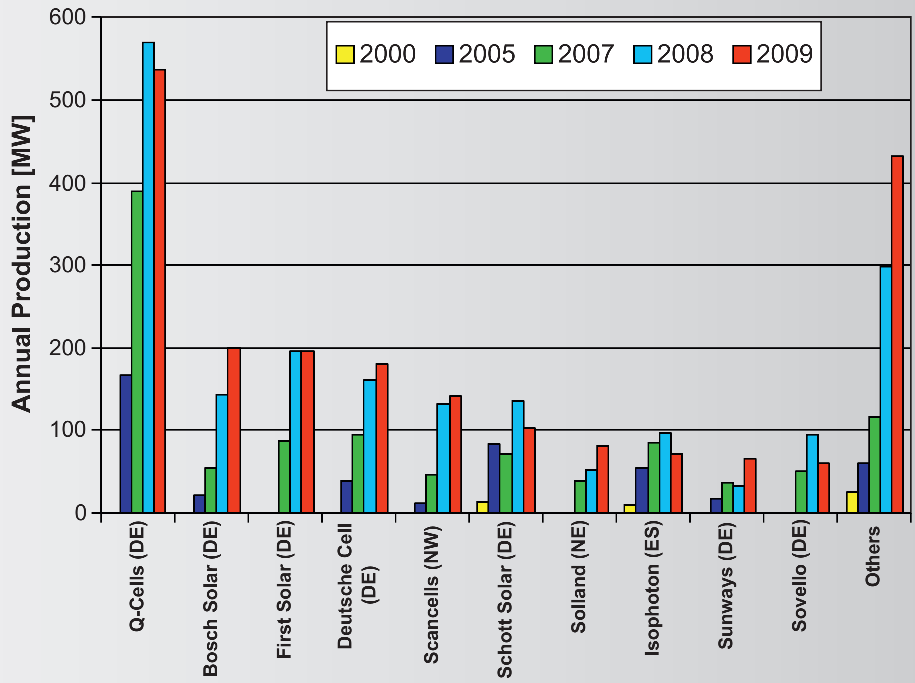
In January 2007, the European Commission published a Communication to the Council and the European Parliament entitled ***"Renewable Energy Road Map – Renewable Energies in the 21st Century: Building a More Sustainable Future"*** [EC 2007]. In this communication the progress of the Member States towards 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 Strategy[27] on jobs and growth[28]. The renewable

Fig. 11: 2009 annual production of the 10 largest PV manufacturers in Europe



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, Pve 2009]. 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 2010].

[27] 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".
[28] Crude oil prices went up from $26/bbl (June 2003) and spiked at $ 147.27/bbl (July 2008), source: Oil report IEA

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 reveal 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 2008[29] [IEA 2008].

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.

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 CO_2-producers.

In 2006, the European Union already surpassed its own White Paper target of 3 GWp cumulative installed capacity for **Renewable Electricity from Photovoltaics** for 2010. The annual growth rate between 2000 and 2009 was 64 % which is almost double what would be needed between 2009 and 2020 in order to reach 12 % of European electricity supply from solar photovoltaic systems (Fig. 12). The main issue to realise such ambitious targets is not whether or not the PV industry can supply the needed systems, but whether or not the electricity grid infrastructure will be able to absorb and distribute the solar-generated electricity.

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, as well as competitive manufacturing technologies, are still required.

[29] Presidency Conclusions of the European Council of 24 March 2006.

4.2 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. An overview about the FP 6 funded projects was published by the European Commission in 2009 [EC 2009a]

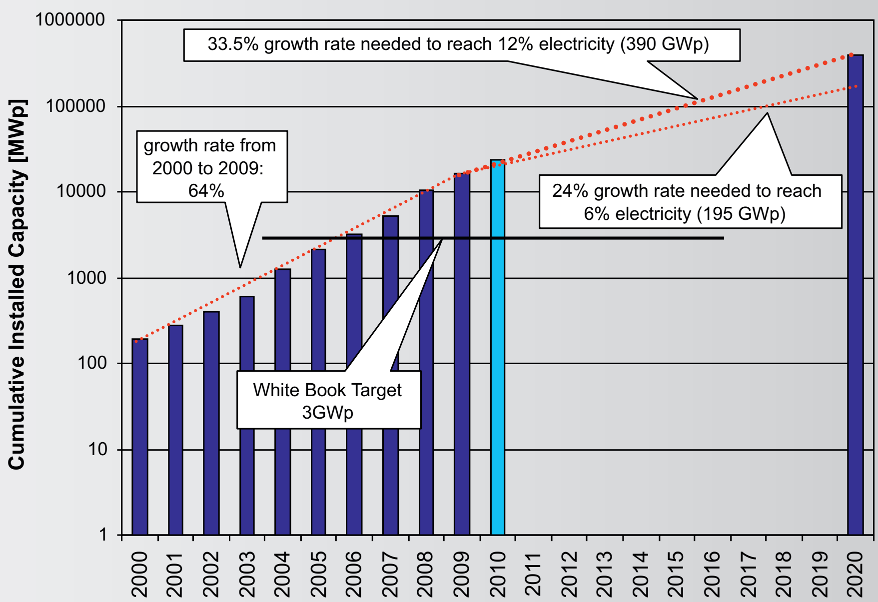
In addition to these technology-oriented research projects, there were Marie Curie Fellow-ships and the "Intelligent Energy - Europe" (EIE) Programme. The CONCERTO Initiative launched by the European Commission was a Europe-wide initiative proactively addressing the challenges of creating a more sustainable 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. 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 the corresponding implementation plan to ensure that Europe maintains industrial leadership [Ptp 2007, 2009].

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 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 have been approved since the publication of the 2009 PV Status Report [Jäg 2009].

Fig. 12: PV growth in the European Union and estimate for 2010.



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

- **PolySiMode:** Improved Polycrystalline-Silicon Modules on Glass Substrates The aim of this project is to improve the efficiency and the cost-effectiveness of thin-film polysilicon solar modules. Thin-film polysilicon solar cells have recently emerged as a promising thin-film alternative to bulk crystalline Si. With Solid Phase Crystallization (SPC) of amorphous Si, CSG Solar AG recently achieved mini-modules with an efficiency of around 10 %, matching the efficiencies of the best European micromorph mini-modules. The efficiency of polysilicon modules will be enhanced in this project by improvement of the crystallographic and electronic quality of the polysilicon material and by the develo-ment of advanced new methods for light confinement. By in-depth characterization of the polysilicon material, a better understanding of the relationship between the processing parameters, the electrical and optical properties of the material and the resulting device properties will be obtained. The main goals are to have large-area polysilicon modules with an efficiency of 12 % and with a cost of 0.7 Euro per Watt peak at the end of the project. The active participation of CSG within this project will allow the consortium to produce module demonstrators by using the pilot line of CSG and also to accurately determine the effect of newly developed process steps on the cost-effectiveness of polysilicon modules. This makes sure that there is a good chance to bring the developed technologies directly into real mass production at the end of the project. These objectives fit very well in the topic ENERGY.2009.2.1.1 - Efficiency and material issues for thin-film photovoltaics. The expected impact of the proposed project is to enhance the efficiency of polysilicon modules, thereby increasing their cost-effectiveness. Since all the main European institutes working on thin-film polysilicon solar cells are joining forces within this project, a substantial acceleration in the improvement of the cost-effectiveness of polysilicon modules is expected.
  Total Budget: € 6,049,282.00, EU contribution: € 4,497,760.00
  Coordinator: Imec, Belgium
  Project duration: 36 months

- **SILICON Light:** Improved material quality and light trapping in thin film silicon solar cells In this project we will increase the efficiency of thin-film silicon solar cells on flexible substrates by solving the issues linked to material quality, interface properties and light management, thus enabling lower production costs per Watt-peak. The general technological objectives of the project are the development of better materials and enhanced interfaces for thin film silicon solar cells, and to transfer the developed processes to an industrial production line. The most important project goals are: 1) Reduction of optical reflection and parasitic absorption losses: Design and industrial implementation of textured back contacts in flexible thin film silicon solar cells. 2) Reduction of recombination losses: Development and implementation of improved silicon absorber material. 3) Reduction of electric losses: Graded TCO layers which minimize the work function barrier between the p-layer and the TCO layer without loss of conductivity and transmission of the TCO. In addition, the top layer of the TCO stack should provide a good protection against moisture ingression. In order to achieve these objectives more in-depth knowledge is needed for several relevant key areas for thin film silicon solar cells. The main scientific objectives are: 1) Identification of the ideal texture for the back contact. This structure should maximize the light trapping in thin film silicon solar cells without deterio ration of open-circuit voltage and fill factor. 2) Paradigm shift for the growth of microcrystalline silicon. In this project we want to show that it is possible to use microcrystalline silicon with high crystalline fractions leading to better current collection without voltage losses, and without crack formation when grown on nano-textured substrates. 3) Deeper understanding of moisture degradation mechanisms of common TCO's like ITO and AZO.
  Total Budget: € 8,848,175.40, EU contribution: € 5,779,519.55
  Coordinator: ECN, The Netherlands
  Project duration: 36 months

- **ThinSi:** Thin Si film based hybrid solar cells on low-cost substrates The ThinSi project will develop a solar cell processing chain for high throughput, cost-effective manufacturing of thin film silicon based solar cells on low-cost silicon substrates. The substrates will be made on the basis of an innovative powder-to-substrate concept. In line with the Workprogramme topic addressed, it will reduce the cost of solar cell modules compared to those made by the conventional wafer based approach. A set of innovative processes will be developed to realise the new low-cost concept and transfer the results into production. The new silicon based substrates will be made from low-cost material using state-of-the-art ceramics technologies. Cost effective processes for the formation of the thin film sili-

con base and the complete solar cell structure will be developed. New methods for optical confinement will be investigated. The electronic properties of individual solar cell materials and their interfaces as well as the relationship between the deposition parameters and the device properties will be analyzed using advanced characterisation and modelling. It will also develop a better understanding of relevant materials issues. Manufacturing procedures suitable for pilot scale pro duction will be developed based on an innovative process chain. The produced solar cells will be assembled into complete modules. The project will develop innovative technologies and equipment prototypes that can easily be scaled up and transferred to production lines by the end of the project. New market opportunities for the SME and industrial partners will be created, both as production tool suppliers and as end-users of the technology.
Total Budget: € 6,186,727.20,
EU contribution: € 4,416,582.10
Coordinator: SINTEF, Norway
Project duration: 36 months

- **HELATHIS:** High Efficient Very Large Area Thin Film Silicon Photovoltaic Modules; Recent photovoltaic market trends point to an increased market share of thin film technologies in addition to an increased volume of module production. In particular for amorphous silicon (a-Si) and microcrystalline silicon (uc-Si) this is driven by the recently increased availability of large area deposition systems from different equipment suppliers. The present project identifies optical light confinement as a key point to increase module efficiency. The optimization of the properties of Transparent Conductive Oxide (TCO) layers at the front contact and the back reflector have to be achieved for large area deposition. Additionally, methods for the reduction of reflection losses at the front glass shall be developed. This optimization has to be done, on the one hand, for single a-Si cell modules and, on the other hand, for modules with a-Si/u-Si tandem structures, where, in the latter case, also an intermediate reflector has to be considered. Objective of the project is to push the implementation of optical layers as part of adapted thin film silicon solar cells into large scale production facilities.
  Total Budget: € 3,132,529.60,
  EU contribution: € 2,108,152.00
  Coordinator: T-Solar Global S.A., Spain
  Project duration: 36 months

- **hipoCIGS:** New concepts for high efficiency and low cost in-line manufactured flexible CIGS solar cells. The Cu(In,Ga)Se2 (CIGS) on glass technology is already heading towards industrial maturity, but to meet the production cost target of below 0.6 €/Wp in mid-term and below 0.4 €/Wp in long-term, development of highly efficient flexible modules is an attractive option. The ultimate advantage of thin-film technology is the possibility of monolithically connected flexible modules produced with high speed roll-to-roll manufacturing systems. Partners of this proposal have already demonstrated a record efficiency of 14.1 % for cells on polyimide and gt;15 % efficiency cells on metal foil using “static deposition” processes. However, transfer of “static deposition” process to “in-line deposition” on moving substrates brings additional challenges for control of layer composition and interfaces. Choice of appropriate substrate and deposition processes to overcome problems of thermal mismatch-related stress are important for high performance and monolithic cell interconnection. The main goal of the project is to develop innovative flexible substrates and deposition processes suitable for the in-line and/or roll-to-roll production of highly efficient solar modules using thinner (< 1 micron) CIGS absorbers and with potential for production costs below 0.6 €/Wp in future. The objective will be achived by developing novel concepts in growth of “high quality” layers and interfaces for efficiency improvement, aiming a new world record efficiency of 16 % on polyimide and low-cost metal (mild steel and Al-based) foils. Also, the implementation of in-line compatible buffer, improvements in interconnect technologies and application of multifunctional top layer will lead to an advancement towards roll-to-roll manufacturability of integrated solar modules. This project will help research institutions to maintain a Global lead in CIGS field and will enable the European industries to implement the research excellence in industrial production of low cost flexible CIGS solar modules in future.
  Total Budget: € 5,018,483.00,
  EU contribution: € 3,644,791.00
  Coordinator: ZSW, Germany
  Project duration: 36 months

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

- **PEPPER:** (Demonstration of high performance processes and equipments for thin-film silicon photovoltaic modules produced with lower environmental impact

and reduced cost and material use). This project tackles major factors relating to micromorph module efficiency and production cost by assessing the influences of glass, TCO and silicon deposition (including in-situ cleaning). The project bridges the gap between research and industrial application by executing new developments and improvements in the field of TCO and PECVD reactors and processes and transferring them to production plants where the full impact on module efficiency and costs can be evaluated. On the other hand it also takes some innovations already used in other applications like different glass types and F2 as cleaning gas and transfers these improvements into the photovoltaic application. While different glass types have a high impact on production cost of solar modules, the utilization of F2 as cleaning gas also has high impact on cost by increasing cleaning rates and decreasing gas cost and also has a strong environmental impact by replacing cleaning gases with a higher global warming potential. All these approaches will not only be developed in parallel but this project will ensure a strong interlink between these activities, e. g. the impact of narrow gap reactors on the F2 cleaning rate. The joint goal of the different work packages is the demonstration of a 157 W micromorph module with a cost of ownership (CoO) reduced to 0.5 €/W. The consortium is comprised of seven partners from four European countries and includes 4 industrial companies (1 equipment supplier, 1 gas supplier and 2 producers of solar modules) and 3 Universities.
Total project cost: € 16.720.648,80,
EU grant: € 9,383,967.60
Coordinator: Oerlikon Solar AG,
Project duration: 36 months

- **PV GUM** (Manufacturing technologies and equipment to produce low-cost PV bituminous-modified roofing membrane with full integration of high efficiency flexible thin-film silicon PV modules). PV roofing membranes have a huge potential for mass deployment. However, currently, major issues still hinder this deployment: adhesives or barrier encapsulants of the existing flexible PV roofs don't meet yet the same reliability as standard construction materials and BIPV is still expensive. The PV-GUM project aims at developing new manufacturing technologies and equipments which will produce a low cost highly efficient flexibly BIPV solar cell on a bituminous roofing membrane (thanks to their proven sustainability, bituminous membranes remain predominantly used for waterproofing flat roofs). The PV-GUM membrane should be very close to the usual bituminous roofing membrane in terms of size, installation process and quality to highly increase the penetration power of PV-GUM in the building market. The PV-GUM membrane will be based on the "Derbibrite" white-coated bituminous membrane technology of Imperbel, PV-GUM coordinator, and the Flexcell flexible PV modules technology. The full integration of the flexible PV modules in the membrane will be performed at the manufacturing stage by a new standardized roll-to-roll encapsulation process to produce PV-laminates followed by a roll-to-roll bitumen impregnation of the PV-laminates. In parallel, a new standardized PECVD reactor and process will be implemented to increase the Flexcell PV cells efficiency to 8 % at least and achieve technology superiority over Unisolar remaining the main supplier for this market. The PV-GUM project targets a PV-laminates production capacity of 20 MW. The high degree of integration of the PV modules and the roll-to-roll lamination allowing process automation will highly decrease the costs /W. Furthermore, sustainability, quality procedures and monitoring in line, compliance to BIPV standards, as well as fully recyclability of the whole product are associated priorities of PV-GUM.
  Total project cost: € 11,091,127.40,
  EU grant: € 6,234,346.00
  Coordinator: Imperbel N.V.
  Project duration: 36 months

Topic ENERGY.2009.2.1.3: Support to the coordination of stakeholders' activities in the field of photovoltaics

- **PV TP-SEC:** Support of the activities of all stakeholders from the PV sector to collaborate together to achieve the 2020 targets. PV TP SEC, will foster the cooperation among all the relevant stakeholders of the PV sector and therefore optimise the coordination of the research work in various technology areas in line with the R&D targets of the Strategic Research Agenda (SRA) developed by the European Photovoltaic Technology Platform (EU PV TP). The Implementation plan of the SRA will lead the European research towards the development of the most promising technologies and as a consequence it will improve the competitiveness of the European research in the world. Moreover, the project will give a fundamental contribution in carrying forward the proposal for the Solar Europe Initiative (SEI), which is driven by the PV industry in the framework of the Strategic Energy Technology (SET) Plan, and its implementation plan in order to reach the following targets: the 12 % of PV electricity produced

by 2020 the grid parity in most Europe by 2020 a competitive position of the EU PV industry by 2020 For the achievement of the R&D targets set in the SRA and the 2020 targets of the SEI it is necessary to continue in supporting, with the appropriate tools, all stakeholders from the PV sector. The main idea which led this consortium to propose this work is based on the need to provide an appropriate support to the stakeholders committed to achieve these ambitious targets.
Project cost: € 959,912.00,
EU Contribution: € 468,116.00
Coordinator: European Photovoltaic Industry Association (EPIA), Belgium
Project duration: 36 months

4.2.1 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.

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” [Epi 2009]. The study explores different deployment scenarios ranging between 4 and 12 %.

4.2.2 Solar Europe Industry Initiative
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 Industry Initiative (SEII) has two pillars: Photovoltaics and concentrated solar thermal power. The Initiative focuses on large-scale demonstration for both technologies and was officially launched at the beginning of June 2010 under the Spanish Presidency.

The intention of the SET-Plan Initiatives is that they are industry led and for this reason the European Photovoltaic Industry Association (EPIA) developed an implementation plan for the first three years of the PV part of the Solar Europe Industry Initiative [Sei 2010].

The implementation plan of the SEII clearly identifies the recommended actions and investment areas, their budgetary implications and the resulting expected measurable benefits for the European society. Within SEII it is envisaged to achieve the following three strategic objectives:

1.SEII will bring PV to cost competitiveness in all market segments (residential, commercial, and industrial) by 2020 (cost reduction);

2.SEII will establish the conditions allowing high penetration of distributed PV electricity within the European electricity system (integration);

3.SEII will facilitate the implementation of large scale demonstration and deployment projects with a high added value for the European PV sector and society as a whole.

In addition to this, the SEII creates the necessary basis for development beyond 2020 and the 2020 targets, supporting the European industry to also play a leading role on the longer term.

4.3 Solar Companies

In the following, some European solar cell manufacturers, not yet mentioned in Chapter 3 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.

4.3.1 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 2009 Isofotón had a production of 70 MW and a production capacity of 180 MW [Pvn 2010].

Isofotón teamed up with the utility Endesa and GEA 21 and together with the Andalusian Department of Innovation, Science and Business, they announced to build the first polysilcon 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 was planned for 2009, but the construction was delayed and the start of construction is now scheduled for 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. In February 2010 the Isofoton North America Inc. received a 55 % job creation tax credit from the Ohio Tax Credit Authority for the planned project.

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.

4.3.2 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 2009 Photowatt had a production of 30 MW [Pvn 2010].

4.3.3 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 2009 the company had a production of 54 MW of polycrystalline solar cells [Pvn 2009].

4.3.4 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 2009, the company had a production of 113 MW (102 MW from Germany, 11 MW from US) [Pvn 2010]. For 2009 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.

In 2007 Wacker Chemie AG and Schott Solar founded a joint venture, Wacker Schott Solar GmbH, to produce multi-crystalline silicon ingots and wafers, which was taken over completely by Schott Solar in 2009.

4.3.5 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 80 MW in 2009 [Pvn 2010].

4.3.6 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 2009 Sovello had a production of 58 MW.

4.3.7 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). Since March 2010 the company is under insolvency administration.

4.3.8 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 2009 the company produced 65 MW.

Sunways opened its second production facility with an initial production capacity of 30 MW in Arnstadt, Germany in 2005, which was expanded to 100 MW in 2008. Total production capacity in 2009 was 116 MW.

4.3.9 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]. For 2009 a production volume of 30 MW is estimated.

4.3.10 Additional Solar Cell Companies

- **AVANCIS GmbH & Co KG** was founded as a joint venture between Shell and Saint-Gobain in 2006. In 2008 commercial production started in the new factory with an initial annual capacity of 20 MW in Torgau, Germany. In 2009 Saint-Gobain took over the shares of Shell and started the construction of a second CIS factory with a total capacity of 100 MW in Torgau. Production in 2009 is estimated at 15 MW.

- **Calyxo GmbH** is a subsidiary of Q-Cells AG, located in Wolfen, Saxony-Anhalt. The company is an early stage manufacturer of CdTe thin-film solar cells and has a pilot plant with a production capacity of 25 MW. In 2008 the company started a 85 MW expansion project, which should be operational in 2011. About 5 MW of CdTe modules were manufactured in 2009.

- **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 concentrator photovoltaic power plants on the commercial level are offered. From 2006 until August 2008, the company manufactured its concentrator modules on a pilot production line before a commercial production line with 25 MW capacity started operation in September 2008. In December 2009 the French Soitech Group acquired Concentrix.

- **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. First commercial sales were done in 2009.

- **Helios Technologies** located in Carmignano di Brenta (PD), Italy, was established in 1981 and became a part of the Kerself Group in 2006. It manufactures solar cells, modules and photovoltaic systems. Current production capacity is 60 MW for solar cells and 50 MW for modules.

- **Inventux Technologies AG** was founded in spring 2007 to manufacture amorphous/microcrystalline thin-film silicon solar modules and broke ground for its 33 MWp factory in Berlin, Germany in September 2007. Commercial production started at the end of 2008.

- **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 build 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 cooperate 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. The first 20 MW phase of this expansion was inaugurated in June 2010.

- **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-tedlar PV modules (Multisol®) and custom made glass-glass PV modules (Optisol®). The company is developing a spheral copper indium selenide based solar cell. The pilot plant opened on 21 June 2007 and it was announced that an industrial production plant with a capacity of 250 MW will be built 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 in 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 line was expanded to 45 MW. A second line, with 90 MW was built in 2009 and the ramp-up started in the second half of 2009 and will continue throughout 2010. Solibro produced about 14 MW in 2009.

- **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. The first 35 MW expansion phase was completed in October 2009. The new production site can be expanded to 75 MW.

- **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 (Flexcell)**, is located in Yverdonles-Bains in Switzerland and produces amorphous silicon flexible modules on plastic film, under the brand name „Flexcell". Q-Cells AG has a 54.2 % share in the company. The first production line on an industrial scale of 25 MW became operational in 2008.

4.3.11 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.

4.3.12 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 in 2011. In 2009, wafer shipment was 239 MW.

4.3.13 Nitol Solar

Nitol Solar (http://www.nitolsolar.com) was established in 2006 as part of the NITOL group, with a production facility based in the Irkutsk region in Russia. The production activity is based on two divisions – the Chemical Division and the Polysilicon Division, which produces trichlorosilane (TCS) and polysilicon (PCS). In January 2007 the company commissioned and commenced operation of a 10,000 MT per year solar-grade TCS production facility and began selling solar-grade TCS in March 2007. The company is currently constructing an additional solar-grade TCS capacity of 15,000 MT per year and the first 3,800 MT phase is expected to become fully operational in 2010.

4.3.14 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 Bjorseth, 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].

The ramp-up of the 185 MW facility in Årdal, Norway, was completed in 2009. In addition, NorSun has a 15 MW production in Vanta, Finland and is planning a 500 MW plant in Singapore for 2013.

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 and the site will allow for subsequent expansions up to an annual production capacity equivalent to 2,000 MW. According to press reports, the bidding process for the construction of the plant should be finished in the second half of 2010.

4.3.15 Schott Solar Wafer GmbH

Schott Solar Wafer GmbH was established as a joint venture of Wacker Chemie AG (Munich) and Schott Solar AG (Mainz) in 2007. In September 2009 Wacker announced its exit from the joint venture and Schott Solar took over the remaining shares. 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 full capacity of 275 MW was 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.

4.3.16 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.

5. India

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 November 2009, the Union Government approved the National Solar Mission which went into force at the beginning of 2010. 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.

5.1 Implementation of Solar Energy[30]

5.1.1 National Tariff Policy

The existing Tariff Policy from 2006 mandates the State Electricity Regulatory Commissions (SERCs) to fix a minimum percentage of energy purchase from renewable energy sources. Eleven state regulators have introduced Renewable Energy Purchase Obligations (RPOs) for the state power distribution companies. The RPOs vary considerably amongst states, from as low as 1 per cent in some states to 10 per cent in others. The mandate has been largely fixed on the basis of the relative renewable energy development potential of the state. However, no specific solar obligations were set.

5.1.2 Special Incentive Package Scheme (SIPS)

In March 2007 the Indian Government announced a semiconductor policy under its SIPS, which will end March 2010 [GoI 2007]. According to this policy, the Government, or its agencies, will provide 20 % of the capital expenditure during the first 10 years for semiconductor industries, including manufacturing activities related to solar PV technology located in Special Economic Zones (SEZ) and 25 % for industries not located in an SEZ. However, non-SEZ units would be exempt from countervailing duty (CVD) — an additional customs duty equal to the excise duty charged on similar domestic products. Table X, below, summarises the incentives available.

Until December 2009, sixteen Solar Photovoltaic (SPV) project applications have been received. Despite that twelve of them had received the “go ahead” already in June 2009, no final financial closure was reported until December 2009. The investment volume over the next ten years of these projects was reported to be more than Rs 760 billion (€ 13.6 billion).

5.1.3 Solar Photovoltaic Programme

The Ministry of Non-Conventional Energy Sources (MNES) has implemented programmes for the development and utilisation of various renewable energy sources in India. The *Solar Photovoltaic Programme* provides Central Financial Assistance (CFA) to implementing agencies for the deployment of PV systems and related activities.

Table 3 shows the indicative targets set for FY 2009 and rest of the 11th plan period (2008 – 2012). These targets could be enhanced subject to availability of funds.

The following photovoltaic systems are eligible under the Programme:

I) Decentralised PV Systems:

- **Solar Home Lighting Systems (SHLS):** for indoor lighting and small electrical power needs of households in rural and other areas. Support would be provided for different models of the SHLS systems, based on 18 Wp, 37 Wp and 74 Wp PV modules.
- **Solar Street Lighting Systems (SLS):** for illumination of streets/ open spaces in rural and urban areas. Support would be provided for SLS systems based on 74 Wp PV modules.
- **Traffic Signals:** PV powered traffic lights in urban areas with conventional power as standby arrangement would be providing support for systems based on up to 100 Wp PV modules.
- **SPV Blinkers:** PV operated LED based traffic blinkers would be supported in systems based on up to 20 Wp PV modules.

Table 2: National Government Incentives available to semiconductor industries under SIPS

Type of unit	Threshold net present value of investment	Incentive in SEZ	Incentive in non-SEZ
Fabrication	Rs 250 billion (€ 4.46 billion[31])	20 %	25 % + exemption from CVD
Eco-system	Rs 100 billion (€ 1.79 billion)	20 %	25 % + exemption from CVD

[30] Indian fiscal year runs from 1 April to 31 March

[31] Exchange rate: 1 € = 56 Rs

- **PV Illuminating Hoardings/Bill boards:** Support would be provided for SPV powered hoardings/ billboards up to 1 kW capacity.

- **SPV Power Packs:** Support would be provided for installation of PV power packs of up to 1 kWp capacity in commercial establishments in urban areas.

- **Stand-alone PV Power Plants (SPPs):** Support would be provided for installation of Stand-alone SPV power plants of capacities between 1 and 10 kWp (without distribution network) and above 10 kWp (with distribution network) for meeting electrical energy needs of small communities, islands and other areas. However, in special cases, SPV power plants of capacities less than 1kWp will also be supported on a case-to-case basis.

- **Other Applications:** Other emerging and new applications of PV technology and specific joint projects with other Ministries/Departments, autonomous Government bodies and other organisations will be supported on a case-to-case basis. The Ministry depending upon their utility will also support SPV systems for community use. The Ministry will also support deployment of SPV systems in areas affected by natural calamities.

II) PV Rooftop Systems for Diesel saving in Urban Areas

Rooftop solar photovoltaic systems (with or without grid interaction) will be supported for installation in industrial and commercial establishments/complexes (excluding manufacturers of PV cells/modules), housing complexes, institutions and others which face electricity shortages and are using diesel generators for back-up power.

Central Financial Assistance for SPV rooftop Systems (with or without grid interaction) will be limited to 100 kWp capacity. Minimum capacity of installation will be 25 kWp. In special cases, smaller capacity systems, not less than 10 kWp, could be considered for financial support from the Ministry. Beneficiaries will exclude manufacturers of SPV cells/modules. Maximum system capacity for sanction of CFA will be linked to the capacity of the existing diesel sets installed by the beneficiary entity. An entity seeking CFA for a particular kWp PV system must have a DG set of at least that capacity installed in its premises.

All types of PV Systems, except solar pumps, can be supported. However, loans will not be provided at reduced rates for systems that are available with capital subsidy. The only exception is for solar generators for which both subsidies and soft loans will be available.

Soft loans are available at an interest rate of 5 % (individuals and other organisations) per annum and 7 % (commercial borrowers who can claim depreciation benefits) and also financial intermediaries who borrow funds from the Indian Renewable Energy Development Agency Limited (IREDA) for on–lending at 5 % or 7 % rate of interest will be charged an interest rate of 2.5 % or 4.5 % respectively by IREDA. Such intermediaries will not be able to claim depreciation benefit and the on-lending arrangement will not be treated as a lease arrangement, through Indian Renewable Energy Development Agency Limited (IREDA). The minimum amount of soft loan is Rs 50,000 (€ 750) for direct users and Rs 100,000 (€ 1,500) for intermediaries. The principal with the interest is repayable in 6 years (including one year moratorium) starting at the end of first year of granting the loan.

Table 3: Indicative Targets for Solar Photovoltaic Programme

Type of PV Systems	Installations [MW]				Financial	
	FY 2009	FY 2010	FY2011	Total	FY2009	11th Plan
decentralised	4.50	4.50	4.50	13.5	Rs 750 million (€ 13.39 million)	Rs 3 billion (€ 53.57 million)
Roof top systems	1.00	1.90	1.35	4.25	Rs 100 million (€ 1.79 million)	Rs 360 million (€ 6.43 million)
Total	5.50	6.40	5.85	17.75	Rs 850 million (€ 15.19 million)	Rs 3.36 billion (€ 60.0 million)

Table 4: Eligibility criteria of Beneficiaries for Solar Photovoltaic Development Programme

Type of PV System	Eligible Categories of Beneficiaries
Solar Home Systems	All Categories of individual beneficiaries and non profit Institutions/Organisations. No individual would be given more than one system.
Street Lighting Systems	All categories of non – commercial institutions/organisations, State Nodal Agency, Electricity Boards, Panchayats, Zilla Parishads and DRDA's.
PV Power Plants / Other Systems	All categories of non – commercial institutions/organisations, State Nodal Agency, Electricity Boards, Panchayats, Zilla Parishads and DRDAs.

5.2 National Solar Mission

The objective of the National Solar Mission is to establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible [GoI 2010].

The Mission will adopt a 3-phase approach, spanning the remaining period of the 11th Plan and first year of the 12th Plan (up to 2012-13) as Phase 1, the remaining 4 years of the 12th Plan (2013-17) as Phase 2 and the 13th Plan (2017-22) as Phase 3. At the end of each plan, and mid-term during the 12th and 13th Plans, there will be an evaluation of progress, review of capacity and targets for subsequent phases, based on emerging cost and technology trends, both domestic and global. The aim would be to protect Government from subsidy exposure in case expected cost reduction does not materialise or is more rapid than expected.

The immediate aim of the Mission is to focus on setting up an enabling environment for solar technology penetration in the country both at a centralised and decentralised level. The first phase (up to 2013) will focus on the capturing of the low hanging options in solar thermal; on promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second phase, after taking into account the experience of the initial years, capacity will be aggressively ramped up to create conditions for up-scaled and competitive solar energy penetration in the country.

To achieve this, the Mission targets are:

- To create an enabling policy framework for the deployment of 20,000 MW of solar power by 2022.
- To ramp up capacity of grid-connected solar power generation to 1,000 MW within three years – by 2013; an additional 3,000 MW by 2017 through the mandatory use of the renewable purchase obligation by utilities backed with a preferential tariff. This capacity can be more than doubled – reaching 10,000MW installed power by 2017 or more, based on the enhanced and enabled international finance and technology transfer. The ambitious target for 2022 of 20,000 MW or more, will be dependent on the 'learning' of the first two phases, which if successful, could lead to conditions of grid-competitive solar power. The transition could be appropriately up-scaled, based on availability of international finance and technology.
- To create favourable conditions for solar manufacturing capability, particularly solar thermal for indigenous production and market leadership.
- To promote programmes for off-grid applications, reaching 1,000 MW by 2017 and 2,000 MW by 2022.
- To achieve 15 million square metres solar thermal collector area by 2017 and 20 million by 2022.
- To deploy 20 million solar lighting systems for rural areas by 2022.

The Solar Mission requires that the Tariff Policy be modified to mandate that the Regulators fix a percentage for purchase of power generated using solar energy. The indicated start point percentage is 0.25 % in Phase I and to be increased to 3 % by 2022.

5.3 Solar Photovoltaic R&D Programme

R&D projects are supported by the Ministry of Non-Conventional Energy Sources at research organisations of the Central or State Governments, autonomous societies, Universities, recognised colleges, Indian Institutes of Technology (IITs) and industries etc., which have suitable infrastructure for undertaking R&D in solar photovoltaic technology. R&D proposals are evaluated by experts and recommended to the Ministry for approval.

R&D is supported on various aspects of solar photovoltaic technology, including development of polysilicon and other materials, development of device fabrication processes and improvements in crystalline silicon solar cell/module technology, development of thin film solar cell technology (based on amorphous silicon films, cadmium telluride (CdTe) films and copper indium diselenide (CIS) thin films, organic, dye sensitized and carbon nano-tubes). MNRE is also supporting development of photovoltaic systems and components used in the manufacturing of such systems. For the 11^{th} Plan, the Ministry has identified the so-called ***Thrust Areas of R&D in Solar Photovoltaic Technology***.

In order to make solar cells and modules cost effective the global R&D efforts are directed to reduce the consumption of silicon and other materials and improve the efficiency of solar cells / modules to achieve significant cost reduction. Further, R&D is also undertaken on non-silicon based solar cell modules and other aspects of PV systems.

The Ministry of New and Renewable Energy Sources has been supporting R&D and technology development in solar photovoltaic technology for more than three decades. During the 11^{th} Plan period it is envisaged that the cost of solar photovoltaic modules can be brought down to about Rs. 120 per Wp.

In order to achieve this goal, the key areas of R&D and technology development have been identified. Research, design and development efforts during the 11^{th} Plan are proposed to be focused on development of (I) polysilicon and other materials, (II) efficient silicon solar cells, (III) thin-film materials and modules, (IV) concentrating PV systems, and (V) PV system design, with the objective of significantly reducing the ratio of capital cost to conversion efficiency. The following are the thrust areas for R&D support in solar photovoltaic technology:

1) Polysilicon Material:

- R&D for producing polysilicon with alternative methods (non triclorsilane) with a direct electricity consumption of less than 125 kWh/kg. The quality of the material should allow for cells with an efficiency higher than 15 %.
- Design, develop and demonstrate at a pilot plant (100 tons annual capacity).

2) Crystalline Silicon Solar Cells and Modules

- Reduction of silicon use to 3 g/Wp for monocrystalline cells by wafer thickness reduction and efficiency increase to ≥ 18 %.
- Develop and produce multi-crystalline silicon ingots/ wafers and produce solar cells with conversion efficiency of 17 % and more in commercial production.
- R&D on alternative device structures to make crystalline silicon solar cells to demonstrate very high efficiency (22-24 % on small size laboratory devices).
- Increase PV module life to 25 years and more, with total degradation within 10 % of the initial rating under STC.
- Design and development of low-cost, low-weight, non-glass type PV modules with effective module life of 10 years or more, with total degradation within 10 % of the initial rating under STC.
- Study and evaluate new materials for use in PV modules.
- Develop low resistance metal contact deposition materials and processes.

3) Thin-Film Modules

R&D on different processes and device structures to make laboratory scale small area (2 cm x 2 cm) devices of efficiency > 10 % using CdTe, CIGS and silicon thin films.

Development of polycrystalline thin-film integrated modules (1 sq ft or more) at pilot plant scale using different materials (CdTe, CIGS, silicon films) to achieve efficiency of > 8 % and life of integrated module > 15 years)

4) New Materials for Solar Cells

- Investigation and characterisation of new materials to determine their suitability for fabrication of solar cells.
- Design and development of new thin-film device structures based on dye sensitised (liquid and solid state) organic, carbon nano-tubes, quantum-dots, etc. materials. Target: laboratory scale efficiency of 5 – 10 %.

5) Concentrating Solar Cells and Modules

- Design and development of concentrator solar cells (concentration ratio of 200 X and more) with module efficiency between 25 – 30 % and testing of concentrating PV system in Indian conditions.
- Development of two axis tracking systems suitable for high concentration PV systems.
- Design and development of heat sinks for mounting solar cells under high concentration.
- Design and development of optical systems to achieve concentration ratio of 200 X and more, with minimum optical aberration.
- Development of silicon and GaAs-based solar cells suitable for use under high concentration (200 X or more)

6)Storage System

- Development of long-life (5,000 cycles or more) storage batteries suitable for use in PV systems/applications.
- Development and testing of new storage systems up to MW scale. It should be possible to store electricity for about 8-10 hours, with storage losses limited to about 10 %.

7) Balance of System and PV Systems

- Design and development of small capacity inverter, including charge controller, with efficiency of 90 % or more, suitable for use in solar lighting systems including LED based lighting systems.
- Design and development of LED based PV lighting systems for indoor and outdoor applications
- Design, development and field-testing of inverters and grid synchronising system components (peak efficiency > 96 % and part load @ 30 % efficiency > 88 %,) used in residential grid interactive rooftop PV systems.
- Field-testing and performance evaluation of grid interactive rooftop residential PV systems.
- Design, development and testing of inverters and grid synchronising system components (peak efficiency > 96 % and part load @ 30 % efficiency > 88 %) for large size (> 500 kWp capacity) grid-connected PV systems.
- Field-testing and performance evaluation of grid interactive large size PV power plant.

8) Testing and Characterisation Facilities

- Upgrade the testing and characterisation facilities for PV materials, devices, components, modules and systems.
- Set up of testing facilities for concentrating PV systems
- Study and evaluate new material, device structures and module designs, etc.

5.4 Solar Companies

In the following chapter, some of the solar companies in India 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.

5.4.1 Bharat Heavy Electricals

Bharat Heavy Electricals Limited (BHEL) is the largest engineering and manufacturing enterprise in the energy-related/infrastructure sector in India today. In 2009 the company increased its manufacturing capacity of silicon solar cells and modules from 3 MW to 8 MW.

In the autumn of 2009, the state-run Bharat Heavy Electricals Ltd (BHEL) and Bharat Electronics Ltd (BEL) announced that they will form a Rs 20 billion (€ 357 million[32]) joint venture by March 2010 to build a 250 MW solar photovoltaic production facility for processing silicon wafers, solar cells and PV modules.

[32] Exchange rate: 1 € = 56 Rs

5.4.2 Central Electronics

Central Electronics Limited (CEL) is a Public Sector Enterprise under the Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology, Government of India. It was established in 1974 with an objective to commercially exploiting the indigenous technologies developed by National Laboratories and R&D Institutions in the country. At the end of 2008, CEL had a production capacity of 10 MW and is planning to increase it up to 25 MW by the year 2012.

5.4.3 HHV Solar Technologies

HHV Solar Technologies is owned by HHV (Hind High Vacuum Company Pvt. Ltd), a manufacturer of vacuum hardware. In 2008 HHV developed a full production line for amorphous silicon solar modules and HHV Solar Technologies set up a thin-film manufacturing line of 10 MW (Phase 1) in 2009. The company has expansion plans for an additional 30 MW (Phase 2) without a specified date.

5.4.4 Indosolar

Indosolar was founded in 2008 and has its production site at Greater Noida (Uttar Pradesh). Within 18 months the company has set up a production capacity of 160 MW for multicrystalline solar cells. The company announced an expansion plan to 360 MW by 2012 and 1 GW by 2015.

5.4.5 KSK Surya Photovoltaic Venture Private Ltd.

KSK Surya has been formed as a joint venture between KSK Power Ventur Plc., an Indian power development company and Surya Power Inc., a thin-film company based in San Jose, California. In October 2009, the company signed a contract with Applied Materials to purchase two Sun Fab thin-film lines with a total capacity of 150 MW.

5.4.6 Moser Baer

Moser Baer Photovoltaic Limited (MBPV) and PV Technologies India Limited (PVTIL) are subsidiaries of Moser Baer India Limited and were launched between 2005 and 2007 with the primary objective of providing reliable solar power as a competitive non-subsidised source of energy.

At the end of 2009, the production capacity was given by the company with 80 MW Crystalline Cells, 80 MW Crystalline Modules, and 40 MW thin-films with expansion plans in place.

5.4.7 Solar Semiconductor

Solar Semiconductor was incorporated in the Cayman Islands in April 2006 and has subsidiaries in the United States and India. Manufacturing plants are located in Hyderabad, India and, according to the company, it had a module production capacity of 195 MW and solar cell capacity of 60 MW at the end of 2009.

5.4.8 Tata BP Solar India Ltd.

Established in 1989, Tata BP Solar is a joint venture between the Tata Power Company and BP Solar. According to the company, the manufacturing capacity for solar cells was increased to 180 MW in 2009. This is a part of their expansion plans to realise a manufacturing capacity of 300 MW by 2012. The module manufacturing capacity is given at 105 MW.

5.4.9 Websol Energy Systems Ltd

Websol Energy Systems Ltd. (formerly Webel SL Energy Systems Ltd.) was established in 1990 and began production in 1994. Its monocrystalline solar cell and module manufacturing facilities are located at Falta Special Economic Zone, Sector II, Falta, West Bengal. According to the company its present manufacturing capacity is 42 MW with plans to ramp it up to 60 MW by May 2011 and to 120 MW by 2012.

5.4.10 XL Telecom & Energy Ltd.

XL Telecom Solar Division started to manufacture solar photovoltaic modules in 1992. According to the company, module manufacturing capacity at the end of 2009 was 192 MW. A capacity expansion of 40 MW for solar modules is under way. In addition, the company is installing a crystalline cell manufacturing plant with a capacity of 120 MW, which should be operational at the end of the second quarter 2010 in the Special Economic Zone (Fab City), Hyderabad in India.

5.4.11 Jupiter Solar Power Ltd

Jupiter Solar Power is a subsidiary of Jupiter International an IT peripherals Marketing and Distribution company. In 2008 the company announced the set-up of two photovoltaic Solar Cell Manufacturing plants in two phases, the first phase at Baddi and the second phase at Kolkata with a total capacity of 34 MW. Further expansion to 180 MW cell capacity and 120 MW module capacity was planned. According to the company, pilot production at the Baddi plant was scheduled to start in January 2010.

5.4.12 Bhaskar Silicon Ltd.

Bhaskar Silicon Ltd. was set up as an independent company by Environ Energy Group as a Solar Energy Solution Provider to build solar photovoltaic power plants and large industrial solar thermal plants. In 2007 the company took over the solar business units of Shell Overseas Investment in India and Sri Lanka. 2008, the company announced that it would build and operate an integrated polysilicon, cell and wafer-processing facility in West Bengal's industrial township, Haldia. with a planned capacity of 2,500 tons of polysilicon.

The company announced it will initially invest Rs 350 crores (€ 62.5 million[31]) to manufacture solar cells based on imported wafers by October 2009. The facility is to add the capability to manufacture wafers in 2011, enabling it to produce 250 megawatts of cells annually. Within two years, the company aims to produce 5,000 metric tons of polysilicon annually and to also supply polysilicon for the semiconductor industry.

6. 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 **3E**s:

- Security of Japanese **E**nergy Supply (Alternatives to oil)
- **E**conomic Efficiency (Market mechanisms)
- Harmony with **E**nvironment (Cutting CO_2 emissions in line with the Kyoto Targets)

6.1 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 CO_2, 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:

- Increasing the amount of installations of solar power generation systems 10-fold by 2020 and 40-fold by 2030, and
- Roughly halving 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 a way so 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).

In July 2009 a new law on the *Promotion of the Use of Nonfossil Energy Sources and Effective Use of Fossil Energy Source Materials by Energy Suppliers* was enacted. 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 Sub-Committee on *Surplus Power Purchase Programme* annually.
- All electricity users will equally bear the costs of the PV surcharge.

The latest development is the 2010 review of the *Basic Energy Plan* which was adopted by the Japanese Cabinet in June 2010 and the development of *Potential Scenarios for Japan's Feed-in Tariff Scheme*.

The *Basic Energy Plan* as well as the *New Growth Strategy* call for the development of a New Innovative Energy Technologies Programme in order to promote the development and diffusion of innovative energy technologies. Photovoltaics is one of the *Priority Areas in Innovative Energy Technology*. Innovative photovoltaic power generation is defined as:

- thin film silicon compounds,
- ultra-thin crystalline silicon compounds,
- thin-film PV cells, and
- organic PV cells.

In order to further promote the development of energy technologies in the future, METI plans to formulate new roadmaps for innovative technologies later in 2010.

6.2 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 94 to 96, 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]. In FY 2007 the Japanese market decreased to 210 MW and only recovered slightly to 230 MW in 2008 [Ohi 2009, Epi 2010]. At the end of 2008, total cumulative installed capacity was 2.15 GW, less then 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.

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 key elements are industry-policy targeted and the goal is to strengthen the renewable energy industry in Japan. This includes the whole value chain from raw material production, cell, module and BOS component manufacturing to the establishment of business opportunities in overseas markets. The strong focus on the establishment of international standards should help to transfer the new Japanese business models world-wide.

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).

In addition to the measures taken by the National Government, over 300 local authorities have introduced measures to promote the installation of PV systems. One of the largest programmes was announced by the Tokyo Metropolitan Government, which plans to support the installation of 1 GW of PV systems in 40,000 households in FY2009 and 2010. 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].

In 2004, NEDO, METI, PVTEC[33] and JPEA[34] drafted the "PV Roadmap towards 2030" (Fig.13) [Kur 2004]. The worldwide changes of circumstances, especially the rapidly growing photovoltaic production and markets, as well as the accelerated growth of energy demand in Asia, together with a changed attitude 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 CO_2 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 4). 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 a 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 for PV2030. For 2050, ultra-high efficiency solar cells with 40 % and even higher conversion efficiency will be developed.

[33] Phtovoltaic Power Generation Technology Research Association
[34] Japan Photovoltaic Energy Association

6.3 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 is 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. In addition to the projects listed below, a number of new initiatives were launched in FY 2010. These projects have relevance for PV and range from R&D of next generation high performance PV systems to a demonstration project on next generation smart power transmission and distribution and R&D on combined storage systems.

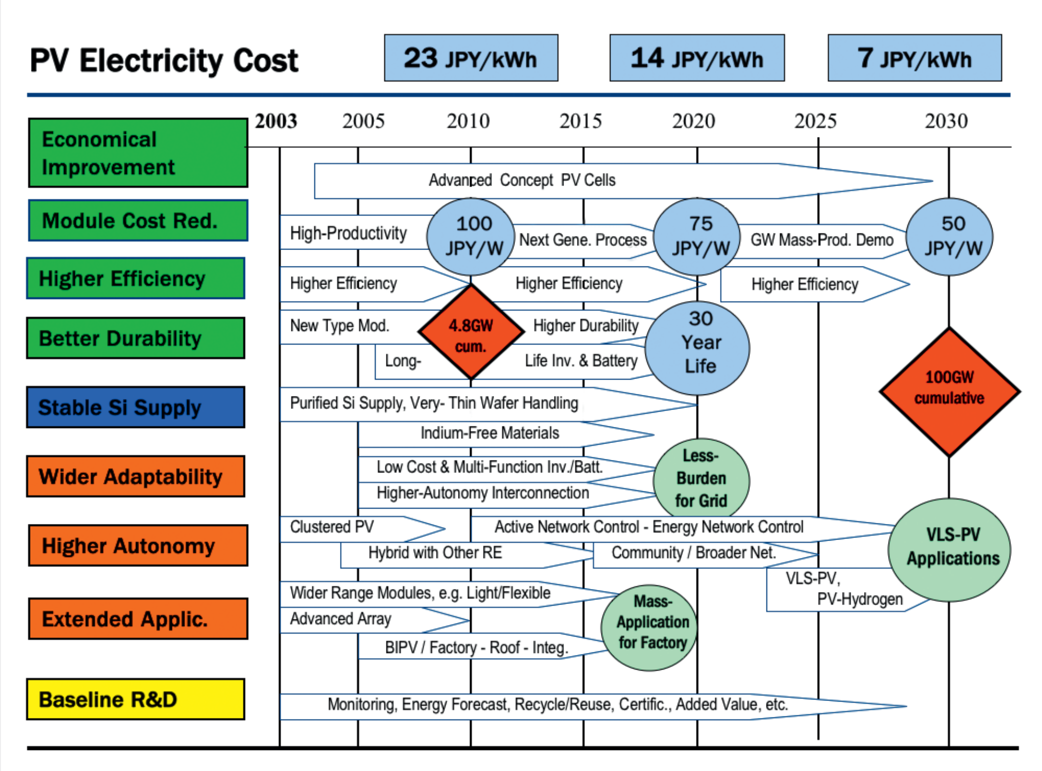


Fig. 13: Japanese Roadmap for PV R&D and market implementation [Kur 2004]

Table 5: Key points of PV2030+ scenario for future growth of PV power generation

Target (completion of development)	**2010 or later**	**2020 (2017)**	**2030 (2025)**	**2050**
Power generation cost	Equivalent to household retail price (23 ¥/kWh)	Equivalent to commercial retail price (14 ¥/kWh)	Equivalent to general power generation (7 ¥/kWh)	Equivalent to general power generation (7 ¥/kWh or below)
Commercial module conversation efficiency (Lab.efficiency)	16 % (20 %)	20 % (25 %)	25 % (30 %)	Ultra-high performance modules with 40 % added
Production for Japanese Market [GW/annum]	0.5 – 1	2 to 3	6 to 12	25 – 35
Production for Export [GW/annum]	ca. 1	ca. 3	30 – 35	ca. 300
Major applications	Single-family houses, public facilities	single/multi-family houses, public facilities, commercial buildings	single/multi-family houses, public facilities, consumer use, charging Evs, etc	consumer use, industries, transport, agriculture, etc., stand alone power source

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.

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/ grapheme 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

Verification of Grid Stabilisation with Large-scale PV Power Generation Systems
FY2006 - FY2010

It is expected that large-scale photovoltaic 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 start-up 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 subsidises 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.

6.4 Solar Companies

In the following chapter those market players in Japan not yet mentioned in Chapter 3 are described briefly. 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.

6.4.1 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, 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 roof-top 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 2009 production was 40 MW [Pvn 2010].

6.4.2 Mitsubishi Electric

In 1974 research and development of photovoltaic modules started. 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, Mitubishi 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 2009 was 120 MW [Pvn 2010].

6.4.3 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 2009 MHI produced 30 MW of amorphous silicon solar cells [Pvn 2010] and it is planned to increase the current production capacity of 128 MW to 600 MW in 2011.

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 50 V or 100 V and power ratings between 24 and 100 Wp.

6.4.4 Solar Frontier:

Solar Frontier is a 100 % subsidiary of Showa Shell Sekiyu K.K. In 1986 Showa Shell Sekiyuki 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 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 900 MW. In 2010 the company changed its name to Solar Frontier and production was given with 43 MW [Ikk 2010].

6.4.5 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 thanks to the significantly reduced silicon use. CV21 entered into an exclusive sale agreement with the FujiPream Corporation in December 2005. According to the 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].

- **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 has been 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 the 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 Reclaim 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.

6.4.6 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.

6.4.7 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 and completed the 100 % takeover in June 2008 [Sun 2008].

6.4.8 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.

6.4.9 Daiwa House Since August 1998, Daiwa House has been selling the “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.

6.4.10 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].

6.4.11 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.

6.4.12 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 CO_2 emissions generated in everyday living, through the use of a solar power generation system, an all-electric system, and the Eco-Life ventilation system.

6.4.13 Additional Silicon Producers

- **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:** This is a 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.

- **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.** This 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.

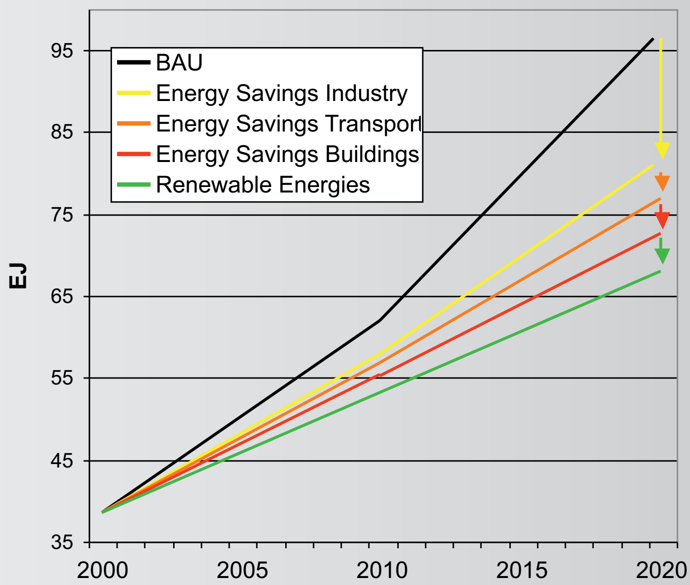
7. People's Republic of China

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 2009 the estimates vary between 3.9 and 4.4 GW. For 2009, capacity increases to over 14 GW have been announced, whereas the figure stands at over 20 GW for 2012. In parallel, China is ramping up its own polysilicon production capacity. In 2009 China already produced about 18,000 metric tons or 20 % of the world-wide production, fulfilling about half of the domestic demand [Bao 2010]. According to the Chinese Ministry of Industry and Information Technology, about 44,000 metric tons of polysilicon production capacity was built in 2009 and a further 68,000 metric tons capacity is under construction. 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 96 EJ 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. 14).

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.

Fig. 14: Scenarios of PRC's fossil energy demand up until 2020 for different scenarios [Fuq 2003]



In June 2007 a joint report by various Chinese Ministries and Government organisations on China's Scientific and Technological Actions on Climate Change pointed out that China's National Climate Change Programme (CNCCP) is well on track to achieve the set target to reduce energy consumption per unit GDP by 20 % by 2010, against the 2005 level [GoC 2007].

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 then 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), estimated 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)[35] in 2000 to 10 to 13 RMB/Wp (1.20 to 1.60)[36] in 2010.

In June 2010, the National Energy Administration (NEA) has published an open tender for 13 solar photovoltaic power stations in the North-western Region and Inner Mongolia, with a total capacity of 280 MW. The bidding procedure is expected to take place in August 2010 and the subsidised electricity price for the PV projects is likely to range between 1.1 – 1.3 RMB/kWh (0.132 – 0.156 €/kWh). There is speculation amongst analysts that the Government may try to define appropriate solar power prices by tendering more projects before announcing a nation-wide solar power feed-in price at the end of the year, as it did for the wind power sector.

On 21 July 2009, a joint notice was released by the Ministry of Finance (MoF), Ministry of Science and Technology (MoS&T) and the National Energy Administration (NEA) announcing subsidies for PV demonstration projects in the following two to three years through a programme called "Golden Sun". The Government announced that it would subsidise 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 at least 500 MW of PV installations. In November 2009, the MoF declared that it had selected 294 projects, with a total capacity of 642 MW. The Ministry estimated that the projects would require construction costs of roughly RMB 20 billion (€ 2.4 billion).

Some Chinese Provinces have announced their own solar programmes with support schemes ranging from investment subsidies or tax incentives for new manufacturing industries as well as solar photovoltaic electricity plants to feed-in tariffs. In July 2010 Shandong Province has set an electricity purchase price of 1.7 RMB/kWh (0.204 €/kWh) for photovoltaic power plants for 2010, which will decrease for new ground-mounted photovoltaic plants to 1.4 RMB/kWh (0.168 €/kWh) in 2011 and 1.2 RMB/kWh (0.144 €/kWh) in 2012.

[35] Exchange rate 2003: 1 € = 9.09 RMB

[36] Exchange rate 2010: 1 € = 8.33 RMB

7.1 PV Resources and Utilisation

The PRC's continental solar power potential is estimated at 70,338 EJ (equivalent to 19,538,400 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 148 % of the world-wide electricity consumption in 2007.

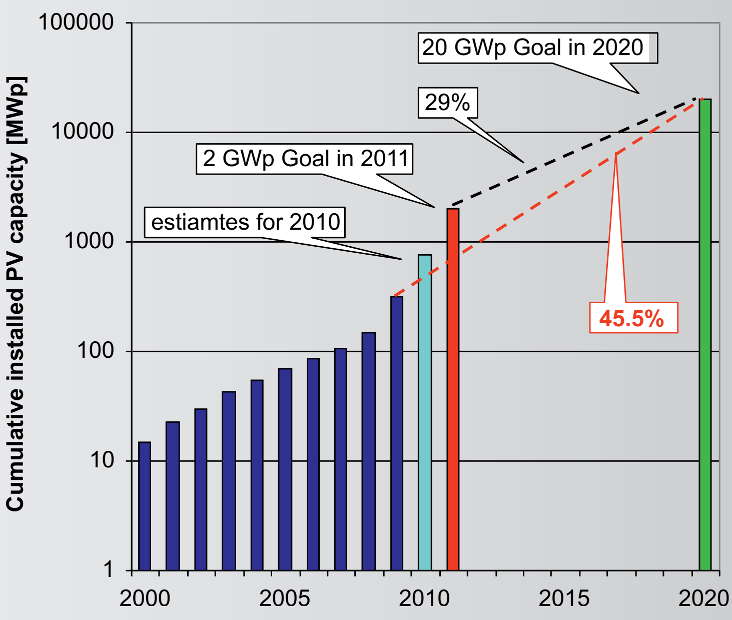
The Standing Committee of the National People's Congress of China endorsed the Renewable Energy Law on 28 February 2005. Although the Renewable Energy Law went into effect on 1 January 2006, the impact on photovoltaic installations in China is however still limited, due to the fact that no tariff has 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.

Fig. 15: Cumulative installed photovoltaic capacities in PRC, estimates for 2010, targets for 2011 and 2020 and annual growth rates.



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 300 MW to 745 MW and the 2020 target from 1.8GW to 28 GW.

- 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.

- 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 Shenzhen. 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.

A number of large scale photovoltaic projects, ranging up to 1 GW, with a total of 12 GW to be realised until 2013, were announced. 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 2010, as a starting point for the development of a GW size market from 2012 on. China is now aiming for 2 GW cumulative installed solar photovoltaic capacity in 2011. In July 2009 the new Chinese energy stimulus plan revised the 2020 targets for installed solar capacity to 20 GW (Fig. 15).

7.2 Solar Companies

In the following chapter, some of the major market players in the PRC, not yet mentioned in Chapter 3, are described briefly. This listing is far from being complete, due to the fact that more than 100 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.

7.2.1 Changzhou EGing Photovoltaic Technology Co. Ltd.

The company was founded in 2003 and works along the complete photovoltaic industry value chain, from the production 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 200 MW across the complete value chain of ingot, wafer, cell and modules and has plans to increase it to 500 MW in 2010. For 2009 a production of 150 MW was estimated.

7.2.2 China Sunergy

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 2009 a production of 160 MW was reported [Pvn 2010].

7.2.3 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 2009, the company reported a production of 97 MW solar cells and 56 MW of modules.

7.2.4 Jiangxi Risun Solar Energy Co., Ltd.

Risun Solar Technologies was established in 2008. The company manufactures mono- and multi-crystalline solar cells and modules. According to the company, the production capacity is 250 MW for modules and 100 MW for solar cells. For 2009 a solar cell production of 50 MW was estimated.

7.2.5 Jiangxi Solar PV Corp.

Jiangxi Solar is a manufacturer of crystalline solar cells located in the Economic Development Zone of Xinyu City, Jiangxi Province. Production started in 2009 with an initial capacity of 200 MW. For 2009 a production of 95 MW was estimated.

7.2.6 Ningbo Best Solar Energy Technology Co., Ltd

Ningbo Best Solar is located in Zhejiang and manufactures mono- and multi-crystalline solar cells and modules. According to the company, the production capacity is 50 MW and the doubling of the capacity is in its planning stage, without a date set.

7.2.7 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. The company manufactures mono- and multi-crystalline solar cells and modules.

7.2.8 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.

7.2.9 Sungen International Ltd.

Sungen is a division of the Hong Kong based Anwell Group and was founded in 2008. The company manufactures amorphous silicon solar cells and modules in Hennan and mono-and multi-crystalline modules in Suzhou. According to the company, the current capacity for amorphous silicon modules of 40 MW is expanded to 120 MW in 2010 and the company has plans to further expand it to 600 MW in 2011 and 1 GW in 2013.

7.2.10 Trony Solar Holdings Company, Ltd.

Trony Solar is located in Shenzhen, Guangdong Province, and manufactures amorphous silicon solar cells and modules for BIPV and consumer applications. According to the company, the current capacity is 110 MW. In May 2010, Trony Technology's “1,000 MW Thin-Film Solar Cell Industrial Base” was recognised as one of the ”Top 500 Modern Industrial Projects“ of Guangdong Province.

7.2.11 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. According to the company, the capacity was 200 MW for solar modules and 75 MW for solar cells in 2009. For 2010, a further expansion to 500 MW modules and 125 MW solar cells is planned.

7.2.12 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 the Yunnan Semi-Conductor Device Factory. In 2005, the production capacity of solar cells was extended to 35 MW and the production of 5-inch solar cells started. In 2006, the capacity was increased to 60 MW and in 2007 the production capacity of solar cells was extended to 100 MW. 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.

7.2.13 Additional Solar Cell Companies

- **Aide Solar** is based in the Economic Development Zone of Xuzhou and was founded in 2003. In 2007 it became a subsidiary of the Taiwanese Panjit Group. According to the company, it has a solar module capacity of 350 MW and a solar cell capacity which is estimated at 300 MW.

- **Amplesun Solar,** located in Xiasha Export Processing Zone, is a private company founded in early 2008. According to the company, it currently has an annual capacity of over 25 MW, with its first amorphous silicon thin film production line which was supplied by ULVAC, Japan. The company plans to reach 120 MW production capacity with tandem junction technology in 2011.

- **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"*. Commercial production of micromorph® solar modules started in July 2009. In December 2009 the company announced to build a second manufacturing facility for their second-generation thin films with a capacity of 240 MW at the Wenzhou Economic and Technological Development Zone.

- **Baoding TianWei Solar Films 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. Phase I of the production was set-up with a capacity of 50 MW and the start of commercial operation was in the second half of 2009. The company plans to reach a capacity of 500 MW 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 JinagSu SuZhou took place in February 2008 and for "Site 2" in JiangXi NanChang in June 2008. In November 2009, phase one with 130 MW production capacity started the ramp up.

- **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 5.7 m^2 (GEN 8.5) solar modules. The 50 MW line is planned to be the first phase of an expected 500 MW capacity plant. Commercial production started in 2009.

- **Hareon Solar** was established as the Jiangyin Hareon Technology Co., Ltd. In 2004 and changed its name to the Hareon Solar Technology Co., Ltd. in 2008. Hareon works along the value chain from the production of silicon ingots to wafers, solar cells and solar modules. Solar cell production started in 2009, with an initial capacity of 70 MW.

- **Jinko Solar Co., Ltd.** was founded by HK Paker Technology Ltd in 2006. Starting from up-stream business, the company expanded operations across the solar value chain including recoverable silicon materials, silicon ingots and wafers, solar cells and modules in 2009. In May 2010, the company went public and is now listed at the New York Stock Exchange. According to the company, manufacturing capacities in 2009 were: 300 MW wafers, 150 MW solar cells and 150 MW solar modules. For 2010 the following expansion is planned: 500 MW wafers, 400 MW solar cells and 500 MW modules.

- **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 increased it to 120 MW in 2009.

- **Shanghai Solar Energy Science & Technology Co.** (SSEC) produces mono-crystalline and multi-crystalline solar cells. According to the company, current production capacity is 150 MW for modules and 35 MW for solar cells.

- **Sunlan Solar Co., Ltd.**, is located in the Shanghe Economic Development Zone. The company has ambitious plans to build up a capacity of 2,000 MW solar polysilicon ingots, 1,000 MW solar cells and 1,000 MW modules by 2015. The first phase to realise a 100 MW module line has been completed and went into commercial operation early 2010. The construction of an ingot plant, with a capacity of 250 MW and a solar cell line with 100 MW, are in progress.

- **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 Jinqiao 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 poly-crystalline solar cells was increased to 200 MW in 2009, and further expansion is underway.

- **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. According to the company, current capacity is 200 MW. For 2009, a production of 100 MW was estimated.

7.3 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.

7.3.1 EMEI Semiconductor Material Factory

EMEI is a subsidiary of the 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 is now operational.

7.3.2 ReneSola Ltd.

ReneSola, previously known as the 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 changed from recycling silicon to make the wafers to an integrated solar company, producing along the value chain from polysilicon to wafers, cells and modules with the acquisition of JC Solar in May 2009. The company increased its wafer manufacturing capacity to 825 MW in 2009 (325 MW mono-crystalline and 500 MW poly-crystalline) and plans to increase this to 1,210 MW (380 MW mono-crystalline and 830 MW poly-crystalline) in 2010.

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. At the end of 2009, phase one with 1,500 tons was operational and the full capacity will come on-line in 2010.

At the end of 2009 the company had a solar-cell production capacity of 120 MW and 135 MW capacity of solar modules. For 2010, an increase to 240 MW for solar cells and 275 MW for solar modules is foreseen. In 2009, 468 MW of wafers were shipped and a cell production of 50 MW is estimated.

7.3.3 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. Production capacity in 2009 was 3,300 tons and a further expansion to 9,300 tons by March 2012 is planned. In May 2010 the company opened its 200 MW module manufacturing plant.

- **China Silicon Corporation Ltd.** (SINOSICO) was established in 2003 and started a 300 ton polysilicon project based on the technology of the **China Enfi Engineering Corporation**, an engineering company established by the China Nonferrous Engineering and Research Institute. The plant was put into operation in October 2005. A 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 capacity became operational at the end of 2008.

- **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 Distict, Yichang City, Hubei Province. This polysilicon project is divided into three stages with unified planning of 4,500 to 5,000 tons per year of high-pure polysilicon. The first stage with 1,500 tons/year was started in 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 subcompany *"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. Production capacity for solar cells was increased to 100 MW in 2009.

- **DALU New Energy Company** is a subsidiary of the 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.

- **Jiaozuo Coal Group Hejing Technique Co., Ltd.** was established as a subsidiary of the Jiaozuo Coal Group of Henan Coal and the Chemical Industrial Group in 2008. The company is building a 1,800 ton polysilicon manufacturing plant.

- **Leshan Ledian Tianwei Silicon Science and Technology Co., Ltd.** is a joint venture formally set up in January 2008 by the Baoding Tianwei Baobian Electric Co., Ltd. and the Leshan Electric Power Co., Ltd.
The company built a polycrystalline facility at Leshan in the Sichuan province, with a capacity of 3,000 t/a. Commercial production started in April 2010.

- **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 2,000 tons.

- **Niking Technology Co., Ltd.** was founded in 1998 and engaged in scientific research and purified polysilicon. The company manufactures polysilicon, ingots and wafers as well as mono- and multi-crystalline solar cells. In 2008 a production of 300 tons of polysilicon was reported and the company planned to increase its capacity to 500 tons in 2009.

- **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.

- **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 pro-duction 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, the **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 the 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.

7.3.4 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. In 2009, Jinglong had 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.

- **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. The Group operates polysilicon reclaiming and upgrading facilities in Shanghai and Jinzhou, which had an aggregate annual designed production capacity of 4,200 tonnes at the end of 2009. In 2009, the Group expanded its activities into the manufacturing of multi-crystalline silicon solar ingots, wafers, modules and system installation. At the end of 2009, annual mono-crystalline and multi-crystalline silicon solar ingots production capacity were 2,000 tonnes and 200 tonnes, respectively, and the annual silicon solar wafer production capacity is 75 million pieces. The downstream photovoltaic module and system installation businesses are done through a 51 % owned joint venture company in Jinzhou, Liaoning Province, the PRC. Annual capacity of the photovoltaic modules production was 50 MW at the end of 2009. For 2010 a doubling of the ingot capacity, as well as the module capacity, is foreseen. A further expansion of the manufacturing capacity of mono-crystalline ingots is planned with the set-up of an additional joint venture company Qinghai Chenguang New Energy Co., Ltd., which should reach its full capacity of 2,000 tons in 2013.

- **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.

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.

8. Taiwan

Within the last five years Taiwan's solar cell production has increased 20fold and is now the second largest producer after the People's Republic of China. Like there, the main focus is on the export and compared to the speed of the ramp-up of production capacities the home market is only developing slowly.

As an emerging industrial nation, Taiwan has focused in its recent past towards an industrial structure with emphasis towards the manufacture industry which resulted in a relatively high energy consumption and greenhouse gas emissions. Over the last 15 years, Taiwan's energy consumption has almost doubled from 2.55 EJ in 1993 to 4.99 EJ in 2007 and then slightly decreased to 4.73 EJ in 2009. This and the fact that Taiwan's current energy supply is still dominated by imported traditional fossil energy sources with more than 90 % (2008: crude oil and petrol products 49.5 %, coal and coal products 32.4 % 91.3 %) makes the country highly vulnerable to price volatility and supply disruptions. In order to enhance security of supply, there is a need to diversify the energy supply as well as there is the need to move to less carbon rich energy sources to reduce greenhouse gas emissions.

8.1 Policies to promote Solar Energy

In 2002 the Renewable Energy Development Plan was approved by the Executive Yuan and 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. The Solar Energy Development Project has a number of long-term goals. It is planned that a total of 7.5 million re-sidents 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 renewable power capacity should reach 6.5 GW.

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$1 trillion (€ 24.4 billion)[38] by 2015. To promote the solar energy industry the Government subsidises manufacturers engaging in R&D and offers incentives to consumers that use solar energy. With the help of official programmes, material suppliers are expanding operations and increasing their investments in the field. In addition, about a dozen manufacturers expressed the intention to invest in fabricating thin-films for solar cells and eight of them will set up their own plants to process the products. The solar energy industry may see its output reach NT$ 450 billion (€ 10.98 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.

In 2008 the Ministry of Economic Affairs (MoEA) published the guidelines of Taiwan's Sustainable Energy Policy [GoT 2008]. The declared policy objective is to create a *Win-Win-Win Solution for Energy, the Environment and the Economy.* To achieve this, sustainable energy policies should support the efficient use of the limited energy resources, the development of clean energy, and the security of energy supply. The following targets were defined:

1. Improvement of energy efficiency: The goal is to improve energy efficiency by more than 2 % per annum, so that when compared with the level in 2005, energy intensity will decrease 20 % by 2015. Supplemented by further technological breakthroughs and proper administrative measures, energy intensity will decrease 50 % by 2025.

2. Development of clean energy:
(1) Reduce nationwide CO2 emission, so that total emission could return to its 2008 level between 2016 ~ 2020, and further reduced to the 2000 level in 2025.

(2) Increase the share of low carbon energy in electricity generation systems from the current 40 % to 55 % in 2025.

3. Securing stable energy supply:
Build a secure energy supply system to meet economic development goals, such as 6 % annual economic growth rate from 2008 to 2012, and 30,000 $ per capita income by 2015.

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 (€ 24.4 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 (0.051 €/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 (€ 732 million) per year, create at least 10,000 jobs and generate output value of NT$ 100 billion (€ 2.44 billion) within two years. In December 2009 the Ministry of Economic Affairs (MoEA) has set the feed-in tariffs, which will be paid for 20 years. For systems between 1 and 10 kW customers can opt for a higher tariff or a lower tariff with an investment subsidy of 50,000 NT$/kW (1,220 €/kW).

- System size 1 to 10 kW:
  Without investment subsidy 14.60 NT$/kWh (0.3561 €/kWh)
  With investment subsidy 11.19 NT$/kWh (0.2729 €/kWh)
- System size 10 to 500 kW: 12.97NT $/kWh (0.3163 €/kWh)
- System size > 500 kW: 11.12 NT$/kWh (0.2712 €/kWh)

[38] Exchange Rate: 1 € = 41 NTD

8.2 Solar Companies

In the following chapter, some of the Taiwanese market players, not yet mentioned in Chapter 3, 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.

8.2.1 Auria Solar Co.

Auria was founded in October 2007 as a joint venture between E-Ton Solar, Lite-On Technology Corp, Hermes-Epitek Corp. and MiTAC-SYNNEX 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.

8.2.2 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 89 MW in 2009 [Pvn 2010]. The company has plans to expand the production capacity to 840 MW by 2012.

8.2.3 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.

8.2.4 Additional Taiwanese Companies

- **AUO Solar** was established as a Business Unit of AU Optronics Corporation (AUO), a global player of thin film transistor liquid crystal display panels (TFT-LCD), in 2009. The company has a strategic in vestment in the Japanese polysilicon manufacturer M. Setec. AUO established a solar module plant in Brno, Czech Republic, which will start mass production in the second quarter of this year and should reach the nameplate capacity of 100MW in 2011. In May 2010, the company announced to set-up a joint venture with SunPower Corporation to construct and operate a solar cell manufacturing facility in Malaysia.

- **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 40 MWp by 2010, to be ramped up to 80 MWp by 2011, and 350 MWp 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 in 2008.

- **Chi Mei Energy Corp.** is a subsidiary of Chi Mei Optoelectronics (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 50 MW 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 90 MW capacity for the initial phase of a 210 MW facility. According to the company, the current capacity is 90 MW.

- **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 was planned to increase the capacity to 16 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. At the end of 2009 the company reported and ingot growing capacity of 360 MW and a wafer capacity of 300 MW. According to the company, it is planned to increase with the expansion of their subsidiaries in China the wafer and cell capacity to 1 GW each at the end of 2010. 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 during 2010.

- **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. According to the company, commercial production on their first CIGS 30 MW line started in December 2009. An expansion with a second line is foreseen for 2010.

- **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. According to the company, they plan to expand their production capacity to 500 MW before 2015.

- **Millennium Communication Co., Ltd.** manufacures 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 25 MW 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 30 MW silicon solar cell production line. A future capacity increase to 90MW is planned.

- **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 plans to expand to 100 MW in 2010 and 200 MW before 2012.

- **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.

- **Tainergy Tech Company Ltd.** was founded in 2007 and went public in March 2010. According to the company, production capacity was 60 MW in 2008 and will increase to 240 MW in 2010.

- **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 was a 30 MW multicrystalline silicon line from Centrotherm, Germany. According to the company, production will increase from the 80 MW in 2009 to 180 MW in 2010 and 270 MW in 2011.

9. The United States

In 2009, the USA was the third largest market with 441 MW of grid-connected PV installations [Sei 2010a] and a total market estimate between 470 and 510 MW. California, New Jersey and Florida account for more than 70 % of the US grid-connected PV market. In 2009 the cumulative installed capacity was around 1.65 GW (1.2 GW grid-connected). Despite a production growth of 43 % to 594 MW [Pvn 2010], the world market share further decreased to about 5 %.

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 1.3 GW fully operational by the end of 2010 and more than 2 GW in 2011 [Fir 2010]. However, most of the production capacity is placed outside the US (1.3 GW Malaysia, 446 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.

9.1 Policies supporting PV

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.

Clean Renewable Energy Bonds (CREBs) were created under the Energy Tax Incentives Act of 2005[37], 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 Reinvest-

[37] added Section 54 to the Internal Revenue Code

ment Act of 2009 expanded funding to $ 2.4 billion (€ 1.85 billion) of new allocations. Of this amount, $ 800 million (€ 615.4 million) is available for State, local, and tribal Governments; $ 800 million (€ 615.4 million) for public power providers; and $ 800 million (€ 615.4 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 (€ 923.1 million) distributed in the first two rounds of funding authorised in 2005. The Energy Improvement and Extension Act of 2008 extended the CREB programme until the end of 2009 and changed some programme rules.

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 (€ 2.23 billion)[38] "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 (€ 2.58 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.

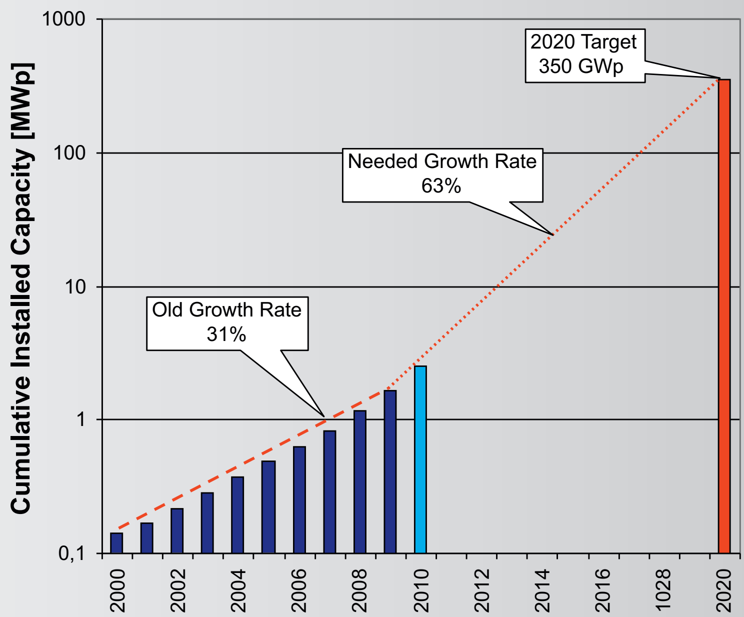
On 23 September 2008, after more than a year of political debate, the US Senate finally voted to extend the tax credits for solar and other renewable energies. On 3 October 2008, Congress approved and the President signed into law the *"Energy Improvement and Extension Act of 2008"* as part of H.R. 1424, 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 Grant Programme (TGP).
- Improvement to the investment tax credit by eliminating ITC penalties for subsidised energy financing.

[38] Exchange rate 1 € = 1.30 $

Fig. 16: SEIA vision for 10% solar electricity in 2020 (2010 figures are estimates).



- 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 (MITC).

The Recovery Act awarded the Office of Energy Efficiency (EERE) $16.8 billion (€ 12.9 billion) for its energy programmes and initiatives. On 27 May 2009, President Obama announced to spend over $ 467 million (€ 359.2 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 (€ 90 million) in Recovery Act funding to accelerate the widespread commercialisation of solar energy technologies across America. $ 51.5 million (€ 39.6 million) will go directly for Photovoltaic Technology Development and $ 40.5 million (€ 31.2 million) will be spent on Solar Energy Deployment, where projects will focus on non-technical barriers to solar energy deployment.

In the run up to the COP 15 meeting in Copenhagen in December 2009, the Solar Energy Industry Association (SEIA) published their new vision to supply 10 % of the US electricity demand with photovoltaic electricity systems [Sta 2009]. Such a scenario would require a cumulative installed capacity of 350 GW in 2020 and is similar to the European vision. This vision is significantly higher than the base-line scenario which adds up to roughly 150 MW or 4.3 % in 2020, or the 84 GW of photovoltaics and concentrated solar power plants as outlined in the "A Solar Grand Plan" for the U.S., published in 2007 [Zwe 2007]. However, for all scenarios it would be necessary to start with laying the foundation of the necessary High Voltage Direct Current (HVDC) transmission system now.

In May 2010 SEIA published a study evaluating the effects of a prolongation of the TGP and MITC on additional job creation and solar installations between 2010 and 2016 compared to the base-line scenario [Eup 2010]. The results are an additional 6.2 GW of PV installations between 2010 and 2016 and more than 160,000 additional new PV related jobs.

In 2009, the average residential electricity price was 11.55 ct/kWh, about 2.6 % higher than the 11.26 ct/kWh in 2008. Figure 17 shows the nation-wide figures for the average residential electricity prices 2010 (January to March) which decreased slightly by 2.6 % from 11.15 ct/kWh to 10.86 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. It should be noted that this is a simplified categorisation and conditions in a State might vary due to solar radiation or weather conditions, as well as that support conditions can change at any time. Nevertheless, it indicates at what turn-key prices for a PV system PV electricity production is competitive with residential electricity prices.

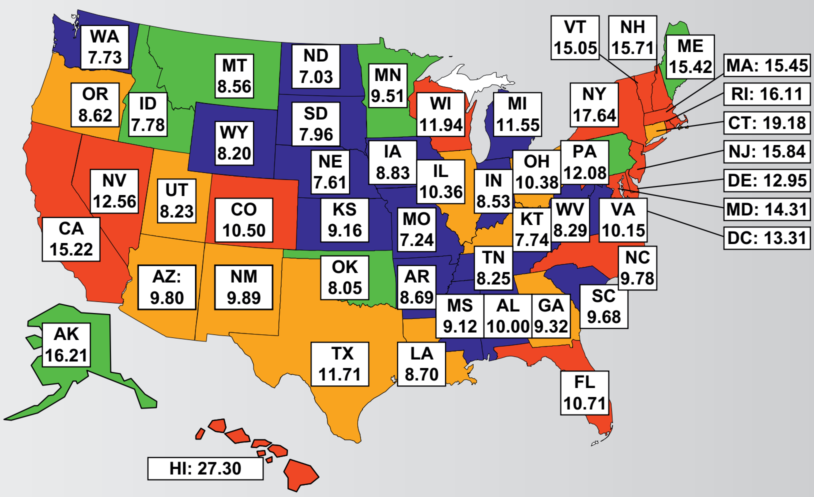
Fig. 17: Average residential electricity prices (¢/kWh) for 2009 [Eia 2010].

Best markets: *(red)*
above 6 $/Wp; 14 States + DC:
California, Colorado, Delaware, Florida, Hawaii, Maryland, Massachusetts, Nevada, New Hampshire, New Jersey, New York, North Carolina, Vermont, Wisconsin, Washington DC

Cost effective markets: *(orange)*
between 4 $/Wp and 6 $/Wp; 12 States
Arizona, Connecticut, Georgia, Illinois, Kentucky, Louisiana, New Mexico, Ohio, Oregon, Rhode Island, Texas, Utah

Emerging markets: *(green)*
between 2.5 $/Wp and 4 $/Wp; 7 States
Alaska, Idaho, Maine, Minnesota, Montana, Oklahoma, Pennsylvania

Significant incentives needed: *(blue)*
below 2.5 $/Wp; 17 States



A geographically more detailed study was published by the National Renewable Energy Laboratory (NREL) in December 2009 [Den 2009]. The study also states: *At $ 6/W, 42 % of residential electricity sales are in utilities where some customers may be at break-even (including customers in States such as Florida, North Carolina, New Jersey, and a growing part of the southwest). **It is important to note that in practice only a fraction of customers in these utility service territories are likely to meet all the criteria** (full retail net metering, good solar exposure, and financing) to be at break-even, and the presence of break-even conditions does not necessarily equate to large consumer adoption. Furthermore, there are budget caps for most current incentive programmes and typically limits on the amount of net-metered systems that can be connected to the grid in a specific utility service territory*[39].

9.2 Incentives supporting PV

Due to the political situation in the US, there are no uniform implementation incentives for photovoltaics. 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[40] (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, 24 States + Puerto Rico)
- corporate tax exemptions
  (Federal Government, 25 States + Puerto Rico)
- sales tax exemptions for renewable investments
  (28 States + Puerto Rico)
- property tax exemptions
  (33 States + Puerto Rico, 1 local)
- buy-down programmes (31 States + District of Columbia, Puerto Rico, Virgin Islands, 301 utilities, 10 local)
- loan programmes and grants
  (Federal Gov., 45 States + District of Columbia, Virgin Islands; 68 utilities, 19 local, 9 private)
- industry support
  (Federal Government, 23 States + Puerto Rico, 1 local)

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.

A study by B.J. Rabe for the Pew Centre on Global Climate Change investigated 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.*

[39] As an example, California restricts net metering to 2.5% of the utility peak demand, while New York and Nevada limit net metering to 1% of utility peak demand. Incentive limits can be even more restrictive with budgets that are often limited to a very small fraction of a system's total demand. See the Database of State Incentives for Renewables and Efficiency http://www.dsireusa.org/.

[40] DoE 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 6: Financial Incentives for Renewable Energy [DSIRE]

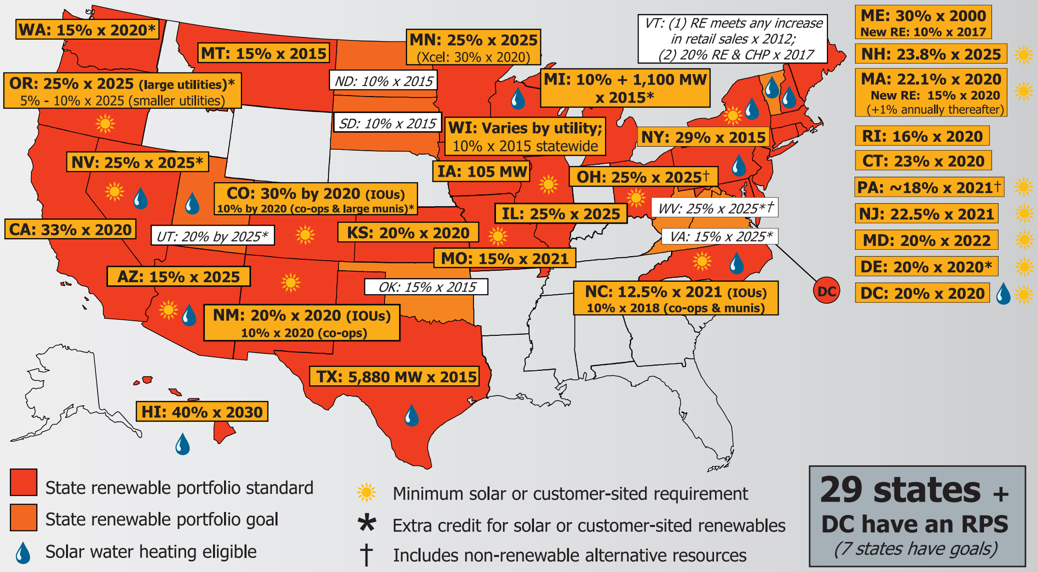
State/Territory	Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Support	Bonds	Performance Based Incentives
Federal Gov.	3	4				3	5	1		1
Alabama	1-S				3-U	1-S	1-S, 2-U			1-U
Alaska						1-S	2-S			1-U
Arizona	4-S	2-S	1-S	2-S	1-S, 6-U		1-U	1-S		
Arkansas					1-S, 1-U		1-U	1-S		
California				1-S	7-S, 38-U, 3-L		1-U, 1-S, 3-L	1-S		1-S, 2-U
Colorado			2-S, 1-L	3-S	2-S, 11-U, 3-L	1-S, 1-L	1-S, 3-U, 1-L			
Connecticut			2-S	1-S	4-S, 2-U	2-S	2-S, 1-P	2-S		
Delaware					3-S	2-S				
Florida			1-S		10-U, 1-L		1-S, 5-U	1-L		2-U
Georgia	1-S	1-S	1-S		1-S, 9-U		1-S			2-U
Hawaii	1-S	1-S		1-L	1-S, 1-U		2-S, 2-U, 1-L	1-S		1-S
Idaho	1-S		1-S	1-S	1-S, 2-U	1-P	1-S		1-S	
Illinois			1-S	2-S	1-S, 5-U	1-S, 1-L, 1-P	2-S		1-S	1-P
Indiana	1-S			1-S	1-S, 25-U	1-S	1-U			1-U
Iowa	1-S	2-S	1-S	3-S	15-U		2-S, 2-U			1-U
Kansas	1-S	1-S		1-S	2-U		1-S	1-S		
Kentucky	1-S	2-S	1-S		1-S, 10-U	1-S	1-S, 1-P, 1-L, 1-U			1-U
Louisiana	1-S	1-S		1-S			2-S			
Maine			1-S		2-S	1-S	2-S, 1P			1-S
Maryland	3-S	3-S	2-S	4-S, 7-L	4-S, 1-L		3-S			1-S
Massachusetts	1-S	2-S	1-S	1-S	2-S, 5-U	4-S	1-S, 1-U, 1-P	3-S		1-S, 1-P
Michigan				2-S	2-S, 5-U	2-S		4-S		1-U
Minnesota			2-S	1-S	5-S, 41-U	2-S, 2-U	6-S, 3-U			1-S, 1-U
Mississippi					1-S, 4-U		1-S, 3-U	1-S		1-U
Missouri		1-S			1-S, 10-U		1-S, 2-U			
Montana	3-S	1-S		3-S	4-U	1-U	1-S	2-S		
Nebraska			1-S		2-U		1-S			
Nevada			1-S	3-S	1-S, 1-U		1-S			1-S
New Hampshire				1-S	2-S, 4-U		3-S, 1-P			
New Jersey			1-S	1-S	6-S	1-S	2-S, 1-U	1-S		2-S
New Mexico	5-S	4-S	4-S	1-S			1-S	1-S	1-S	3-U
New York	3-S	1-S	1-S	2-S, 1-L	6-S, 5-U	1-S	3-S, 1-L	2-S		
North Carolina	1-S	1-S	1-S	2-S	6-U	1-S	3-S, 1-U			3-U, 1-P
North Dakota	1-S	1-S		2-S	1-U		2-U			
Ohio		1-S	1-S	2-L	3-U, 1-P	6-S	2-S, 1-U, 1-L	1-S		
Oklahoma		1-S			3-U		4-S, 2-U	1-S		
Oregon	1-S	1-S		1-S	7-S, 21-U	1-P, 2-S	3-S, 9-U	1-S		1-S, 1-U
Pennsylvania				1-S	1-S, 1-U	7-S, 1-U, 2-L	6-S, 5-L, 1-U	3-S		1-S
Rhode Island	1-S	1-S	1-S	2-S	1-U	1-S	1-S, 1-P			1-P
South Carolina	1-S	2-S	1-S		6-U		1-S, 5-U			1-S, 2-U, 1-P
South Dakota			1-S	3-S	5-U		2-U			
Tennessee				1-S	1-S, 1-U	2-S	2-S, 1-U	1-S		1-U
Texas		1-S		1-S	26-U, 2-L	2-S	2-S	1-S		2-U
Utah	1-S	1-S	1-S		1-S, 6-U			1-S		
Vermont	1-S	1-S	1-S	1-S	1-S	2-S, 1-U	2-S, 1-P			1-S, 2-U
Virginia				1-S	1-S		1-S	2-S		1-U
Washington			1-S		17-U	1-P, 1-L	11-U	1-S		1-S, 3-U
West Virginia	1-S	1-S		1-S						
Wisconsin	1-S	1-S	1-S	1-S	6-S, 6-U	1-S, 2-U	2-S, 1-U, 1-L	2-S		5-U
Wyoming			1-S		2-S, 3-U		1-S			
D.C.					1-S		1-S			
Palau										
Guam										
Puerto Rico	2-S	1-S	2-S	1-S	4-S			1-S		
Virgin Islands					1-S	1-S	1-S			
N. Mariana Isl.										
Amer. Samoa										
Totals	**42**	**40**	**38**	**64**	**419**	**65**	**170**	**38**	**3**	**57**

Table 7: Rules, Regulations & Policies for Renewable Energy [DSIRE]

State/Territory	PBF	RPS	Net Meter-ing	Inter-connection	Contractor License	Equipment Certification	Access Laws	Construction & Design Standards	Green Power Purchase	Required Green Power
Federal				1				1		
Alabama										
Alaska			1-S				1-S			
Arizona		1-S,	1-S, 1-U	1-S	1-S	1-S	1-S	3-S, 4-L		
Arkansas			1-S	1-S				1-S		
California	1-S	1-S	1-S	1-S	1-S		2-S, 8-L	3-S, 8-L		
Colorado	1-L	1-S	1-S	1-S			1-S, 1-L	2-S, 4-L		1-S
Connecticut	1-S	1-S	1-S	1-S	1-S			2-S		
Delaware	1-S, 2-U	1-S	1-S	1-S			1-S	2-S		1-S
Florida		1-U	1-S	1-S	1-S	1-S	1-S, 1-L	1-S		
Georgia			1-S	1-S			1-S	1-S, 1-L		
Hawaii	1-S	1-S	1-S	1-S	1-S		1-S	2-S		
Idaho			3-U				1-S			
Illinois	1-S	1-S	1-S	1-S				2-S		
Indiana			1-S	1-S			1-S	1-S, 1-L		
Iowa		1-S	1-S	1-S			1-S			1-S
Kansas		1-S	1-S	1-S			1-S	1-L		
Kentucky			1-S	1-S			1-S			
Louisiana			1-S, 1-L	1-S			1-S			
Maine	1-S	1-S	1-S	1-S	1-S		2-S	2-S		1-S
Maryland		1-S	1-S	1-S			1-S	1-S		
Massachusetts	2-S	1-S	1-S	1-S			1-S	3-S		
Michigan	1-S	1-S	1-S	1-S	1-S			2-S, 1-L		
Minnesota	1-S	2-S	1-S	1-S		1-S	1-S	1-S		
Mississippi										
Missouri		1-S, 1-L	1-S	1-S			1-S	1-S		
Montana	1-S	1-S	1-S, 1-U	1-S			1-S			1-S
Nebraska			1-S	1-S			1-S			
Nevada		1-S	1-S, 1-U	1-S	1-S		1-S	1-S		
New Hampshire		1-S	1-S	1-S			1-S			
New Jersey	1-S	1-S	1-S	1-S			2-S	4-S		
New Mexico		1-S	1-S, 1-U	1-S			1-S	1-S		1-S
New York	1-S	1-S, 1-U	1-S, 1-U	1-S			1-S	2-S, 1-L		
N. Carolina		1-S	1-S	1-S			1-S, 1-L	1-S, 11-L		
North Dakota		1-S	1-S				2-S			
Ohio	1-S	1-S	1-S	1-S			1-S	1-S		
Oklahoma		1-S	1-S					1-S		
Oregon	1-S	1-S	1-S, 1-U	1-S	1-S	1-S	1-S, 2-L	3-S, 1-L		1-S
Pennsylvania	1-S	1-S	1-S	1-S				1-S		
Rhode Island	1-S	1-S	1-S				1-S	1-S		
S. Carolina			3-U	1-S				1-S		
South Dakota		1-S		1-S			1-S	2-S		
Tennessee					1-S		1-S			
Texas		1-S,1-L 1-U	2-U	1-S				2-S, 5-L		
Utah		1-S	1-S, 3-U	1-S	1-S		1-S	1-L		
Vermont	1-S	1-S	1-S	1-S			1-S			
Virginia		1-S	1-S	1-S	1-S		2-S	1-S, 1-L		1-S
Washington		1-S	1-S, 1-U	1-S			1-S	1-S, 1-L		1-S
West Virginia		1-S	1-S							
Wisconsin	1-S	1-S	1-S	1-S	1-L		1-S, 1-L	1-S		
Wyoming			1-S	1-S						
D.C	1-S	1-S	1-S	1-S				1-S		
Palau										
Guam		1-S	1-S					1-S		
Puerto Rico			1-S	1-S	1-S	1-S				
Virgin Islands		1-S	1-S				1-S	1-S		
N. Mariana Isl.										
Amer. Samoa			1-S							
Totals	**23**	**45**	**68**	**44**	**14**	**5**	**58**	**101**	**0**	**9**

Fig. 18: States with Renewable Portfolio Standards in the US (July 2010); Figure © DSIRE [Dsi 2010].

Renewable Portfolio Standards



The Union of Concerned Scientists predicted 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 State level will have a significant impact on reducing CO_2 emissions. By 2025, these State RPSs will reduce total annual CO_2 emissions by more than 183 million tons of CO_2, 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.

In July 2010, 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 an RPS (Fig. 18). In 16 States and the District of Columbia the RPS include minimum solar or distributed generation (DG) provisions (Fig. 19).

Another very important measure for photovoltaics is the grid access. In July 2010, 43 US States, Washington DC, Guam, Puero Rico the Virgin Islands and American Samoa- had implemented a net metering policy (Fig. 20). In Idaho, South Carolina and Texas some utilities have agreed on voluntary net metering.

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 14 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.

Legend for table 6 and 7, pages 93/94:
S = State/Territory **L** = Local **U** = Utility **P** = Private
Source: North Carolina Solar Centre, North Carolina State University research based on information in the Database of State Incentives for Renewable Energy (DSIRE) (2010). 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:
http://www.eere.energy.gov/greenpower/markets/certificates.shtml?page=2

Fig. 19: US States with RPS Policies with Solar/DG Provisions (July 2010); Figure © DSIRE [Dsi 2010].

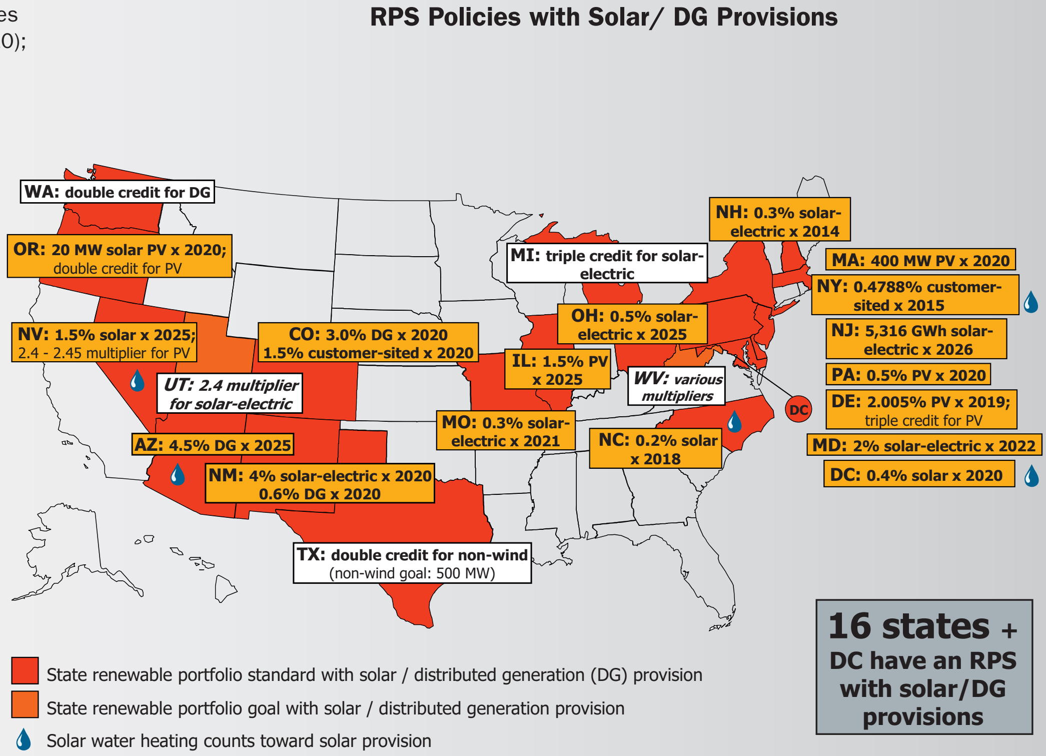
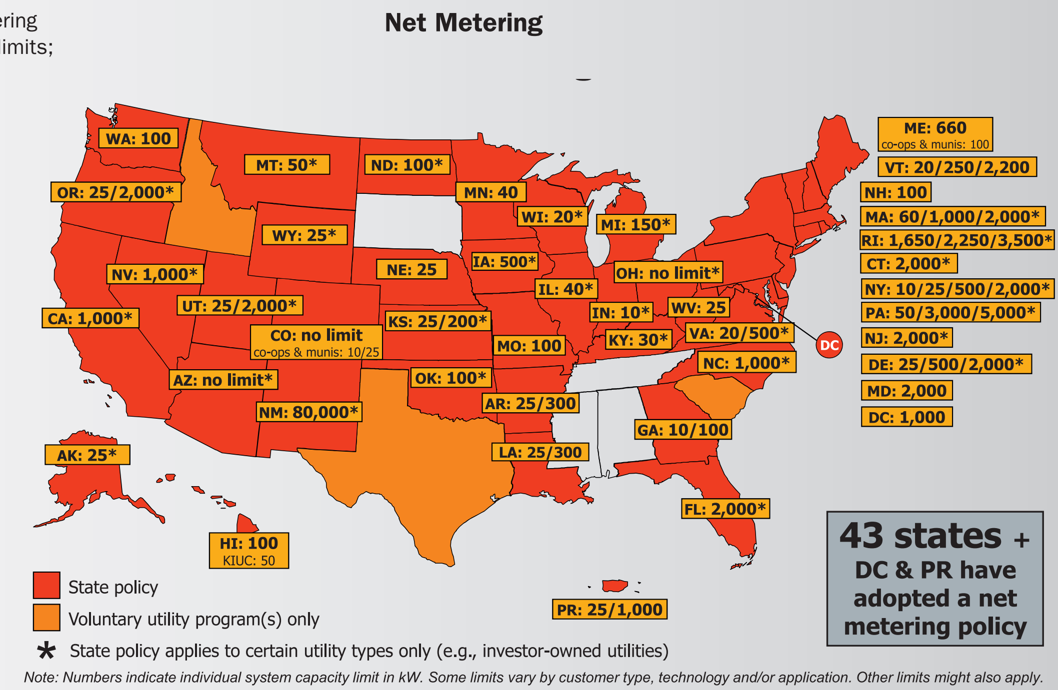


Fig. 20: US States with Net-metering in the US (July 2010) and upper limits; Figure © DSIRE [Dsi 2010].



9.3 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 (€ 130.8 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 market-place. 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 analysing 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 emphasises 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 market-place.

6. Exploring and developing the next generation of PV technologies that will reach consumers beyond the SAI timeframe (post-2015).

7. Assisting US industry in regaining its leadership role in the global solar market-place.

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 8), 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.

Table 8: Solar Programme Cost Targets

Market Sector	Current U.S. Market Price Range for Conventional Electricity(¢/kWh)	Levelised Cost of Energy (¢/kWh)		
		Benchmark	Target	
		2005	2010	2015
Utility	4.0 - 7.6 2.6 - 24.5 [b]	13–22	13–18	5–7
Commercial [a]	5.4 - 15.0 [c] 6.09 - 20.89 [d]	16–22	9–12	6–8
Residential	5.8 - 16.7 [c] 7.5 - 23.3 [d]	23–32	13–18	8–10

a) In many commercial applications, utility costs are tax deductible. In these cases, the cost of solar energy should be compared to the effective market price, considering tax effects.
b) 2010 (January – June) Wholesale Day Ahead Prices at Selected Hubs, Peak on ICE platform [Eia 2010].
c) Electricity costs cited in the Solar Programme.
d) Electricity costs in 2010 (January to March) [Eia 2010].

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.

9.3.1 Solar Technology Research Plan

The US 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 and Module Development
2. PV Materials and Cell Technologies
3. Testing and Evaluation
4. Grid / Building Integration

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

9.3.1.1 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 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 PV research focuses on two areas:

(1) Next Generation PV: In April 2007, DoE made the first 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 multijunction, 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.

(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 scale-up. Technology neutral, this project encompasses innovative PV cell and module technologies suitable for residential roof-top, commercial roof-top, and utility markets.

9.3.1.2 Prototype Components and Systems

The Solar America Initiative's research in component and system prototypes emphasises 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 tax-payers get the best value for their investment in these projects.

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

DoE announced American Recovery and Reinvestment Act (Recovery Act) awardees in January 2010.

9.3.1.3 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 three 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 commercialisation of US-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 US 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 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 becomes 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.

9.4 Advanced Research Projects Agency – Energy

In 2006 the National Academies released a report “Rising Above the Gathering Storm”, where it recognised the need to re-evaluate the way the United States spurs innovation. The report included the recommendation to establish an Advanced Research Projects Agency – Energy (ARPA-E) within the Department of Energy (DoE), which was realised in 2007.

ARPA-E is modelled after the successful Defense Advanced Research Projects Agency (DARPA), the Agency responsible for technological innovations such as the Internet and the stealth technology. Specifically, ARPA-E was established and given the following objectives:

1. To bring a freshness, excitement, and sense of mission to energy research that will attract many of the US's best and brightest minds — those of experienced scientists and engineers, and, especially, those of students and young researchers, including persons in the entrepreneurial world;

2. To focus on creative "out-of-the-box" transformational energy research that industry by itself cannot or will not support, due to its high risk, but where success would provide dramatic benefits for the nation;

3. To utilise an ARPA-like organisation that is flat, nimble, and sparse, capable of sustaining for long periods of time those projects whose promise remains real, while phasing out programmes that do not prove to be as promising as anticipated; and

4. To create a new tool to bridge the gap between basic energy research and development/industrial innovation.

Amongst the 37 selected projects from the first funding announcement there is only one solar photovoltaic project:

- **Direct Wafer: Enabling Terawatt Photovoltaics**
  Brief Description of Project: For photovoltaics (PV) to reach terawatt scale and meet ARPA-E targets for energy generation, emissions reductions, and US jobs, three criteria must be met. PV devices must be:

  (1) low-cost (< $0.80/Wp);

  (2) made from abundant materials; and

  (3) high-efficiency (> 20 %).

  Crystalline silicon is the only technology capable of meeting all three criteria. The single barrier limiting silicon's market penetration is the 35-year-old grand challenge of making high-efficiency wafers without the cost and waste of sawing. 1366 Technologies has developed a kerfless wafering process called Direct Wafer, which eliminates PV's cost and supply limitations, transforming PV from niche to mainstream. Direct Wafer slashes fully-installed PV system costs from ~$ 4/W to ~$ 2/W (~$ 0.10/kWh) and reduces wafer capital costs by 90 %. By dramatically lowering cost, Direct Wafer could enable 600 GW of installed PV in the US by 2025, save 694 million metric tons of annual CO_2 emissions, and spawn a multi-million-job domestic PV manufacturing and installation industry.

9.5 Solar Companies

In the following chapter those solar companies not yet mentioned in Chapter 3 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.

9.5.1 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 2009 was 104.6 MW [Pvn 2010]. According to the company, the first 80 MW phase of their new facility in Devens was opened in June 2008, followed by the second 80 MW in 2009. Due to the economic pressure the company decided to move its module manufacturing activities to China, but continuing the wafer and cell production in Devens.

In 2009 Evergreen announced the signing of a manufacturing agreement with Jiawei Solar, PRC [Eve 2009]. Under the agreement, Evergreen will manufacture String Ribbon wafers 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 2009, production capacity was increased to 180 MW and 58 MW were produced.

9.5.2 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. GSE aims for 175 MW production capacity in 2010 [Glo 2008]. In 2009, about 20 MW production was estimated.

9.5.3 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 1½ 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 2009 increased to 120 MW [Pvn 2010].

9.5.4 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. In November 2009 the company started mass production at their factory in Longmount (CO), which will have a capacity of 200 MW, once 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 was completed in 2009 and it is planned to ramp-up to full capacity during 2010. 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.

- **Miasolé** was formed in 2001 and produces flexible CIGS solar cells on a continuous, roll-to-roll production line. The company has installed two 20 MW production lines in its Santa Clara facility. In January 2010, the company announced that it installs a second 20 MW line and another 60 MW are planned, bringing the total capacity to 100 MW at the end of 2010 [Mia 2010].

- **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 GIGS. 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]. In September 2009 the company announce the completion of its European 640 MW panel-assembly factory [Nan 2009]. Production for 2009 was estimated at 12 MW.

- **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 and is located in Menlo Park, CA. 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 (plan is currently on hold). Signet India was founded in 2007 and had 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. In April 2010, NREL confirmed that flexible CIGS solar panels manufactured on Solo Power's pilot production line have achieved aperture conversion efficiencies of 11 % [Sol 2010a]. According to the company, current capacity is 10 MW, with an expansion of 75 – 100 MW in planning.

- **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. For 2009 a production of 30 MW was reported [Pvn 2010]. In 2010 the company announced to increase their total production capacity to 300 MW by 2011 [Sol 2010b].

- **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). In 2009 the capacity was increased to 96 MW and in July 2010 the company announce to further increase capacity to 170 MW [Sun 2010].

- **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. In 2009 the company completed the installation of its first 25 MW roll-to-roll photovoltaic manufacturing equipment.

9.5.5 AE Polysilicon Corporation

AE Polysilicon (AEP) was founded in 2006 to manufacture polysilicon for the solar industry. The main investors are Motech (33.3 %) and since 2010 Total Gas & Power USA (25.4 %). 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). In May 2010 AEP announced that it expects to complete fluidised bed reactor (FBR) testing and begin commercial production in the coming months. When operating at full capacity, the initial facility will support the production of approximately 250 MW per year of installed solar energy. The company expects to ramp up the initial facility to full capacity (1,800 tons) by late 2011.

9.5.6 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 hade adjusted their planning for the polysilicon manufacturing plant located in Pocatello (ID) to 3,500 tons, in order to meet customer demand [Hok 2008]. Due to the difficult economic conditions, pilot production was delayed almost a year and started in April 2010. The company plans to start commercial shipments of polysilicon in the third quarter of 2010 [Hok 2010].

10. **Outlook**

New investment in clean energy technologies, companies, and projects held steady in the second quarter of 2010 at $ 33.9 billion (€ 26.01 billion) as a drop in investment in European projects was offset by a continuing boom in China and a bounce back in the US, according to new estimates from research firm Bloomberg New Energy Finance [Blo 2010a]. With $ 3.5 billion (€ 2.7 billion) in new asset financing and $ 1 billion (€ 770 million) in Venture Capital (VC) and Private Equity (PE) financing solar energy was second only to wind.

The Photovoltaic Industry has changed dramatically over the last few years. China has become the major manufacturing place followed by Taiwan, Germany and Japan. Amongst the 15 biggest photovoltaic manufacturers in 2009, only three had production facilities in Europe, namely First Solar (USA, Germany and Malaysia), Q-Cells (Germany and Malaysia) and Solarworld (Germany and USA). In 2009, amongst the top ten manufacturers were four companies from China (Suntech N° 2, Yingli Solar N° 6, JA Solar N° 7, Trina Solar N° 9); two from Japan (Sharp N° 3, Kyocera N° 8) and the USA, but with international manufacturing sites (First Solar N° 1 (USA, Germany, Malaysia) and Sunpower N° 10 (Philipines)), one German (Q-Cells N° 4 (Germany and Malaysia)) and one Taiwanese (Gintech N° 7 (Taiwan and China)).

The implementation of the 100,000 roofs programme in Germany in 1990 and the Japanese long-term strategy set in 1994, with a 2010 horizon, were the start of an extraordinary PV market growth. 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. Since 1990 PV, production has increased 250 fold from 46 MW to about 11.5 GW in 2009. This corresponds to a CAGR of a little more than 33.5 % over the last twenty years. Statistically documented cumulative installations world-wide accounted for 22 GW in 2009. The interesting fact is, however, that cumulative production amounts to 32 GW over the same time period. Even if we do not account for the roughly 4 GW difference between the reported production and installations in 2009, there is a considerable 6 GW capacity of solar modules which are statistically not accounted for. Parts of it might be in consumer applications, which do not contribute significantly to power generation, but the overwhelming part is probably used in stand-alone applications for communication purposes, cathodic protection, water pumping, street, traffic and garden lights, etc.

The temporary shortage in silicon feedstock, triggered by the 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 rebounced and fluctuates in the 70 to 90 $/bbl range since August 2009. It is obvious that the fundamental trend of increasing demand for oil will drive the oil price higher again. Already in March 2009, the IEA Executive Director, Nobuo Tanaka, warned in an interview 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.

The Energy Watch Group estimated that world-wide spending on combustibles, fuels and electricity was between $ 5,500 billion (€ 4,231 billion) to 7,500 billion (€ 5,769 billion) in 2008 [Ewg 2010]. Between 7 and 10 % or $ 550 billion (€ 423 billion) of this amount is spent in energy subsidies each year according to an IEA study which was discussed at the G20 meeting in Toronto in June 2010, as reported by the Financial Times [FT 2010]. This annual subsidy would be sufficient to install about 140 GW of PV systems annually world-wide.

The FT cited Fatih Birol, chief economist at the IEA in Paris, saying that removing subsidies was a policy that could change the energy game "quickly and substantially". *"I see fossil fuel subsidies as the appendicitis of the global energy system which needs to be removed for a healthy, sustainable development future"* he told the FT.

This is in line with the findings of a 2008 UNEP report Reforming Energy Subsidies [UNEP 2008], which concluded: *Energy subsidies have important implications for climate change and sustainable development more generally through their effects on the level and composition of energy produced and used. For example, a subsidy that ultimately lowers the price of a given fuel to end-users would normally boost demand for that fuel and the overall use of energy. This can bring social benefits where access to affordable energy or employment in a domestic industry is an issue, but may also carry economic and environmental costs. Subsidies that encourage the use of fossil fuels often harm the environment through higher emissions of noxious and greenhouse gases. Subsidies that promote the use of renewable energy and energy-efficient technologies may, on the other hand, help to reduce emissions.*

Table 9: Evolution of the cumulative solar electrical capacities until 2050 [Gre 2010, IEA 2008a, IEA 2010]

Year	**2010** [GW]	**2020** [GW]	**2030** [GW]	**2050** [GW]
Greenpeace* (reference scenario)	14	80	184	420
Greenpeace* ([r]evolution scenario)	18	355	1,036	2,968
Greenpeace* (advanced scenario)	21	439	1,330	4,318
IEA Reference Scenario	10	30	< 60	non competitive
IEA ACT Map	22	80	130	600
IEA Blue Map	27	130	230	1,150
IEA PV Technology Roadmap	27	210	870	3,155

* 2010 values are extrapolated as only 2007 and 2015 values are given

The IEA study estimates that energy consumption could be reduced by 850 million tons equivalent of oil – or the combined current consumption of Japan, South Korea, Australia, and New Zealand – if the subsidies are phased out between now and 2020. The consumption cut would save the equivalent of the current carbon dioxide emissions of Germany, France, the UK, Italy, and Spain.

Over the last 20 years, numerous studies about the potential growth of the photovoltaic industry and the implementation of photovoltaic electricity generation systems were produced. In 1996 the Directorate General for Energy of the European Commission published a study "Photoltaics in 2010" [EC 1996]. The medium scenario of this study was used to formulate the White Paper target of 1997 to have a cumulative installed capacity of 3 GW in the European Union by 2010 [EC 1997]. The most aggressive scenario in this report predicted a cumulative installed PV capacity of 27.3 GW world-wide and 8.7 GW in the European Union for 2010. This scenario was called *"Extreme scenario"* and it was assumed that in order to realise it a number of breakthroughs in technology and costs as well as continuous market stimulation and elimination of market barriers would be required to achieve it. The reality check reveals that even the most aggressive scenario is lower than what we expect from the current developments. At the moment a cumulative installed capacity of 32 to 37 GW world-wide and 24 to 26 GW in Europe are predicted for the end of 2010.

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 new scenarios for the future growth of PV. Table 9 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 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[41] (€ 20 trillion) [IEA 2008b] over $ 4 trillion (€ 3.01 million) more then predicted in the WEO 2007. According to this data, $ 13.6 trillion (€ 10.5 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 (€ 80.8 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 550 ppm (ACT Map) and one with 450 ppm (Blue Map). The IEA estimates that the additional costs compared to the Reference Scenario for the time period from 2010 – 2030 of the ACT scenario of $ 4.1 trillion (€ 3.15 trillion) are more than covered by the fuel savings of $ 7 trillion (€ 5.38 trillion) during the same time. In the case of the Blue Map scenario, costs of $ 9.2 trillion (€ 7.01 trillion) are estimated which would only be compensated partially by fuel cost savings of $ 5.8 trillion (€ 4.46 trillion) due to higher electricity costs. However, the cost difference of $ 3.4 trillion (€ 2.62 trillion) would just be equal on average 0.2 % of annual world GDP. The extra cost amounts to $ 14 (€ 10.77) per person and year.

[41] In 2007 $

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 very competitive market situation, and to compensate the advantage 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.

Despite the fact that Europe – especially Germany – is still the biggest world market, the European manufacturers are losing market shares in production. This is mainly due to the 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, the European share will further decrease, even with a continuation of the 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 2009 and the first half of 2001, the announcements from new companies which want to start a PV production, as well as established companies to increase their production capacities, continued to increase the expected overall production capacity. 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 about 30 % in 2015. However, the number of thin-film expansion projects which are caught between the fact that margins are falling, due to decreasing module prices and the need to raise additional capital to expand production in order to lower costs, is increasing.

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 being more expensive in the market than conventional energy sources. Nevertheless, electricity production from photovoltaic solar systems have already proved now that it can be cheaper than peak prices in the electricity exchange in a wide range of countries and if the new EPIA and SEIA visions can be realised, electricity generation cost with photovoltaic systems will have reached grid parity in most of Europe and the USA 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.

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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 decade 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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