INTERNATIONAL ENERGY AGENCY

CO-OPERATIVE PROGRAMME ON PHOTOVOLTAIC POWER SYSTEMS

Task 1

Exchange and dissemination of information on PV power systems

National Survey Report of PV Power Applications in Germany 2011

Prepared on behalf of

BMU – German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

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by
Dr. Lothar Wissing
Forschungszentrum Jülich GmbH
Projektträger Jülich, PTJ-EEN
D-52425 Jülich

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Definitions, Symbols and Abbreviations

For the purposes of this and all IEA PVPS National Survey Reports, the following definitions apply:

PV power system market: The market for all nationally installed (terrestrial) PV applications with a PV power capacity of 40 W or more.

Installed PV power: Power delivered by a PV module or a PV array under standard test conditions (STC) – irradiance of 1 000 W/m^2, cell junction temperature of 25^{o}C, AM 1,5 solar spectrum – (also see 'Rated power').

Rated power: Amount of power produced by a PV module or array under STC, written as W.

PV system: Set of interconnected elements such as PV modules, inverters that convert d.c. current of the modules into a.c. current, storage batteries and all installation and control components with a PV power capacity of 40 W or more.

Module manufacturer: An organisation carrying out the encapsulation in the process of the production of PV modules.

Off-grid domestic PV power system: System installed to provide power mainly to a household or village not connected to the (main) utility grid(s). Often a means to store electricity is used (most commonly lead-acid batteries). Also referred to as 'stand-alone PV power system'. Can also provide power to domestic and community users (plus some other applications) via a 'mini-grid', often as a hybrid with another source of power.

Off-grid non-domestic PV power system: System used for a variety of industrial and agricultural applications such as water pumping, remote communications, telecommunication relays, safety and protection devices, etc. that are not connected to the utility grid. Usually a means to store electricity is used. Also referred to as 'stand-alone PV power system'.

Grid-connected distributed PV power system: System installed to provide power to a grid-connected customer or directly to the electricity grid (specifically where that part of the electricity grid is configured to supply power to a number of customers rather than to provide a bulk transport function). Such systems may be on or integrated into the customer's premises often on the demand side of the electricity meter, on public and commercial buildings, or simply in the built environment on motorway sound barriers etc. They may be specifically designed for support of the utility distribution grid. Size is not a determining feature – while a 1 MW PV system on a rooftop may be large by PV standards, this is not the case for other forms of distributed generation.

Grid-connected centralized PV power system: Power production system performing the function of a centralized power station. The power supplied by such a system is not associated with a particular electricity customer, and the system is not located to specifically perform functions on the electricity grid other than the supply of bulk power. Typically ground mounted and functioning independently of any nearby development.

Turnkey price: Price of an installed PV system excluding VAT/TVA/sales taxes, operation and maintenance costs but including installation costs. For an off-grid PV system, the prices associated with storage battery maintenance/replacement are excluded. If additional costs are incurred for reasons not directly related to the PV system, these should be excluded. (E.g. If extra costs are incurred fitting PV modules to a factory roof because special precautions are required to avoid disrupting production, these extra costs should not be included. Equally the additional transport costs of installing a telecommunication system in a remote area are excluded).

Field Test Programme: A programme to test the performance of PV systems/components in real conditions.

Demonstration Programme: A programme to demonstrate the operation of PV systems and their application to potential users/owners.

Market deployment initiative: Initiatives to encourage the market deployment of PV through the use of market instruments such as green pricing, rate based incentives etc. These may be implemented by government, the finance industry, electricity utility businesses etc.

Final annual yield: Total PV energy delivered to the load during the year per kW of power installed.

Performance ratio: Ratio of the final annual (monthly, daily) yield to the reference annual (monthly, daily) yield, where the reference annual (monthly, daily) yield is the theoretical annual (monthly, daily) available energy per kW of installed PV power.

Currency: The currency unit used throughout this report is €

PV support measures:

Enhanced feed-in tariff	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility business) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility business, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility business, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility business (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass)
PV requirement in RPS	a mandated requirement that a portion of the

	RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Activities of electricity utility businesses	includes ‘green power’ schemes allowing customers to purchase green electricity, operation of large-scale (utility-scale) PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building’s energy foot print or may be specifically mandated as an inclusion in the building development

Foreword

The International Energy Agency (IEA), founded in November 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD) which carries out a comprehensive programme of energy co-operation among its 23 member countries. The European Commission also participates in the work of the Agency.

The IEA Photovoltaic Power Systems Programme (IEA-PVPS) is one of the collaborative R & D agreements established within the IEA and, since 1993, its participants have been conducting a variety of joint projects in the applications of photovoltaic conversion of solar energy into electricity.

The 22 participating countries are Australia (AUS), Austria (AUT), Canada (CAN), China (CHN), Denmark (DNK), France (FRA), Germany (DEU), Israel (ISR), Italy (ITA), Japan (JPN), Korea (KOR), Malaysia (MYS), Mexico (MEX), the Netherlands (NLD), Norway (NOR), Portugal (PRT), Spain (ESP), Sweden (SWE), Switzerland (CHE), Turkey (TUR), the United Kingdom (GBR) and the United States of America (USA). The European Commission, the European Photovoltaic Industry Association, the US Solar Electric Power Association and the US Solar Energy Industries Association are also members.

The overall programme is headed by an Executive Committee composed of one representative from each participating country or organization, while the management of individual Tasks (research projects / activity areas) is the responsibility of Operating Agents. Information about the active and completed tasks can be found on the IEA-PVPS website www.iea-pvps.org

Introduction

The objective of Task 1 of the IEA Photovoltaic Power Systems Programme is to facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of photovoltaic power systems. An important deliverable of Task 1 is the annual Trends in photovoltaic applications report. In parallel, National Survey Reports are produced annually by each Task 1 participant. This document is the German National Survey Report for the year 2010. Information from this document will be used as input to the annual Trends in photovoltaic applications report.

The PVPS website www.iea-pvps.org also plays an important role in disseminating information arising from the programme, including national information.

1 EXECUTIVE SUMMARY

1.1 Installed PV power

New installed (power) [3]	7.500 MWp
Total installed power [3]	24.820MWp

1.2 Costs & prices

Turnkey Prices of Typical PV Applications (VAT excluded (19%), net, prices rounded, prices at end of 2011, usually grid connected) [11]

1 – 2	kWp:	2.540 €/kWp
2 – 5	kWp:	2.260 €/kWp
5 - 10	kWp:	2.040 €/kWp
> 10	kWp:	1.790 €/kWp

1.3 PV production

Production of cells (Si + thin film) [2]	2.919,2 MWp
Production of wafers [2]	2.270 MWp
Production of crystalline Si-Moduls [2]	2.302 MWp
Production of feedstock silicon [2]	37.150 t
PV power generation [3]	19.000 GWh

1.4 Budgets for PV in 2011

R&D budget for PV projects by BMU [7]	39,0 Mio. €
R&D budget for PV projects by BMBF [7]	~ 17,0 Mio. €

2 THE IMPLEMENTATION OF PV SYSTEMS

2.1 Applications for Photovoltaics

Economy and Policy

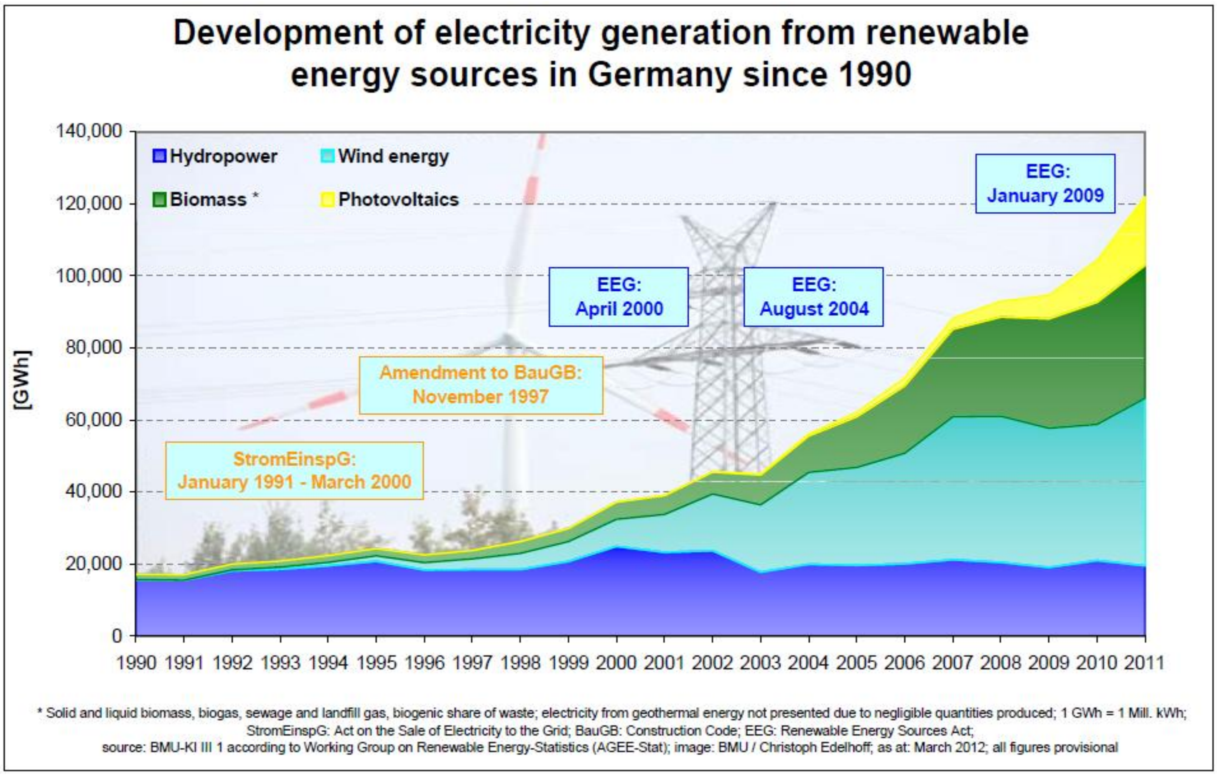
Germanys future energy supply will be environmental friendly, reliable and economical feasible. The German Federal Government paved the way for this target when announcing the German Energy Concept in autumn 2010. Moreover, it was decided in 2011 to terminate the production of nuclear power until 2022.

Concerning renewable energies, the Concept states that this energy source will contribute the major share to the energy mix of the future. With respect to the electricity supply, the share for renewable energies is expected to reach 35% in 2020 and 80% in 2050. The first half of 2011 showed already a share of 20%.

Photovoltaic (PV) is part of this development. At present, a PV capacity of 24.82 GW is connected to the grid meaning again an annual increase of 7.4 GW. The installation of PV systems in Germany is still driven by the Renewable Energy Sources Act (EEG) on the one hand and a noticeable decrease of system prices on the other hand.

Due to decreasing system prices and a hard competition with cheaper Chinese modules in the German Market, a lot of German PV companies went into financial problems or had to close their business. This trend became even stronger in 2012 with a lot shut downs of production facilities or insolvencies.

Since 2004, Germany is among the countries with the highest annual PV installation world-wide. This remarkable development is based on the “Renewable Energy Sources Act (EEG)” [1]. The EEG rules the input and favourable payment of electricity from renewable energies by the utilities. For PV, the feed-in tariff depends on the system size and whether the system is ground mounted or attached to a building. Since 2009, there is also a tariff for self consumed power. All rates are guaranteed for an operation period of 20 years.



Initially, a uniform and yearly reduction of the PV tariffs was foreseen. On the background of a constantly rising number of installations, a mechanism was introduced to adapt the EEG tariff to the market growth. Under this scheme, the reductions are increased or decreased if the marked deviates from a predefined corridor. For 2010 to 2012, the corridor is currently set between 2 500 and 3 500 MW yearly. With around 7 500 MW installed in 2011 the corridor was surpassed considerably. Therefore, additional adaptations of tariffs in 2012 are under discussion.

In Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) takes the responsibility for the renewable energies within the Federal Government. The main driving force for the PV market in Germany is the Renewable Energy Sources Act (EEG) [9]. In terms of achieving expansion targets for renewable energies in the electricity sector, the EEG is the most effective funding instrument at the German government's disposal. It determines the procedure of grid access for renewable energies and guarantees favourable feed-in tariffs for them.

Research and Development (R&D) is conducted under the new 6th Programme on Energy Research "Research for an environmental friendly, reliable and economical feasible energy supply" [10] which came into force in August 2011. Within this framework, the BMU as well as the BMBF (Federal Ministry of Education and Research) support R&D on different aspects of PV. Main parts of the programme are administrated by the Project Management Organisation PtJ in Jülich.

2.2 Total photovoltaic power installed

Since the beginning of 2009 the owner of new PV systems are legally obliged to register their systems at the German Federal Network Agency (GFNA). Another official source is the "Working Group on Renewable Energy Statistics" (AGEE-Stat) working on behalf of the BMU. This group supplies a lot of data for all renewable energies and in detail. Furthermore BSW supplies data emphasised on the market developments. The fourth source is the "German Trade and Invest (GTI)" collecting data to support foreign investors to enter the German market. Interesting are its list of companies working in the PV market updated quarterly.

There are nearly no information about off-grid non domestic, grid connected centralized systems or stand-alone systems in Germany because the electricity supply is completely connected to the public grid. Therefore, there is no need for these systems and regarding the total installed capacity of PV, these systems are negligible, estimated less than 1 ‰ of grid connected PV capacities and will not be mentioned in this report anymore.

Due to the official registration procedure by German Federal Network Agency the accuracy of these data can be assumed better than ± 1 %.

Since 2009 AGEE-Stat takes over the data the German Federal Network Agency.

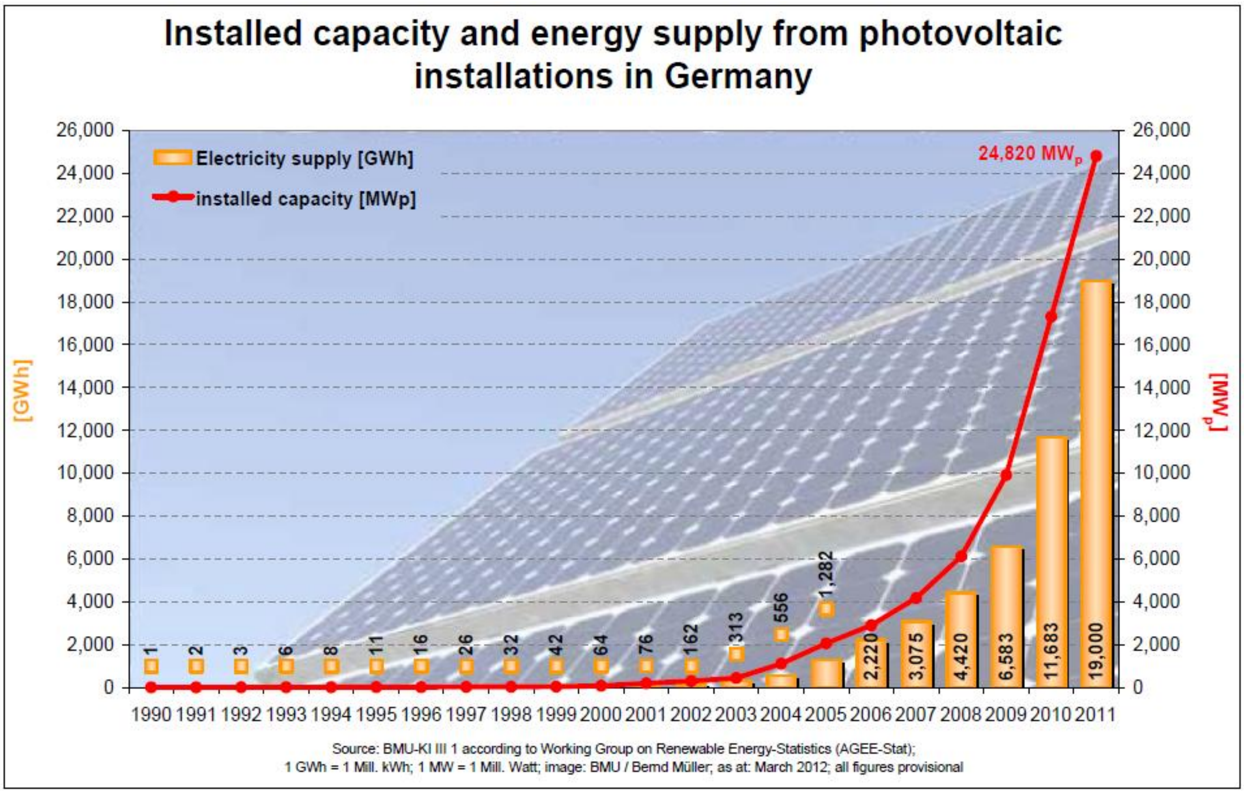
Table 1: PV power installed during calendar year 2011 in 2 sub-markets.

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total
PV power installed in 2011 (kW)	n.n.	n.n.	7500	n.n.	7500

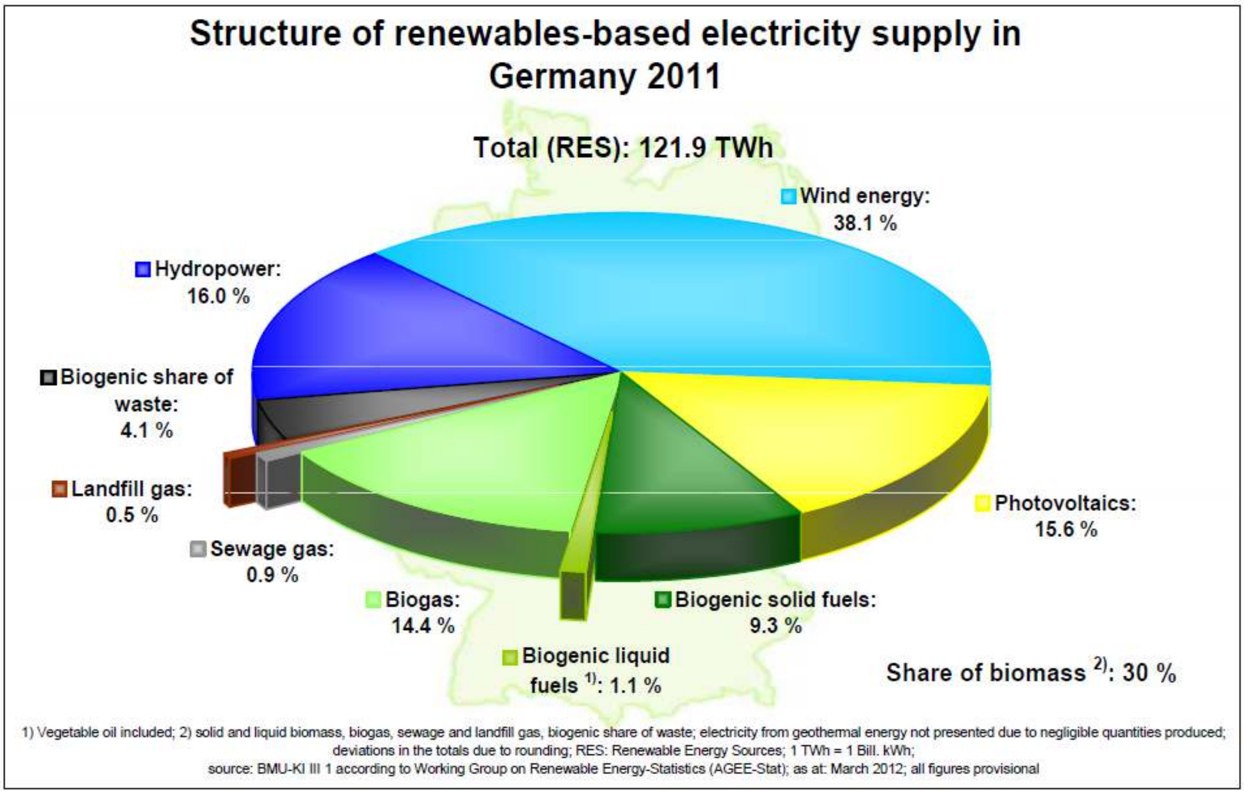
A summary of the cumulative installed PV Power, from 2000-2011, broken down into four sub-markets is shown in table 2.

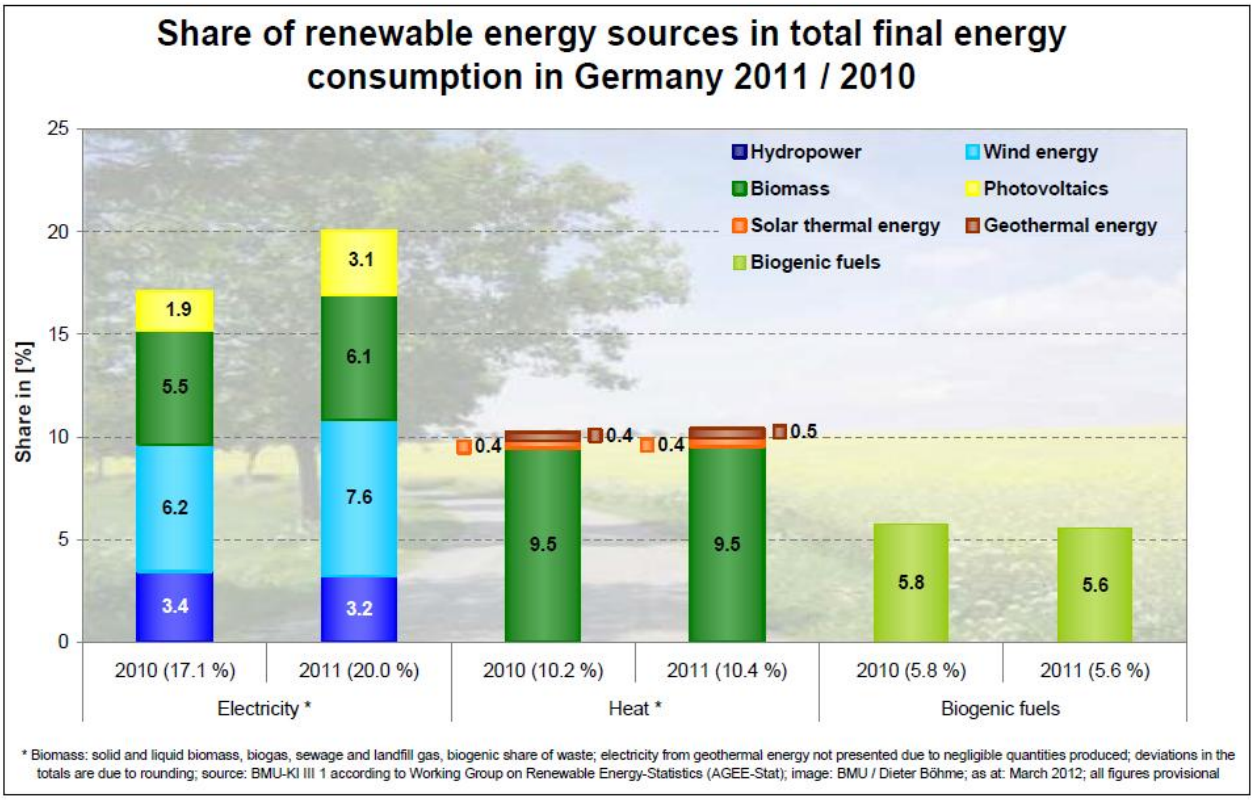
Table 2: The cumulative installed PV after [3],

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Off-grid	14	16	20	23	26	29	32	35	40	45	50	
Grid-connected	76	186	296	435	1105	2056	2899	4170	6120	9914	17.320	24.820
Total	90	202	316	458	1131	2085	2931	4205	6160	9959	17.370	24.820



Germany has a wide range of policy and promotional initiatives. First of all is the mentioned EEG with the feed-in tariff. Additionally there are tax credits for investments in PV and loans by KfW for measures to reduce energy consumption and the application of renewable energies in buildings. Some states award grants for PV plants.





A lot of journals offer information about PV, some only specific for PV, others under the theme “Renewable Energy”.

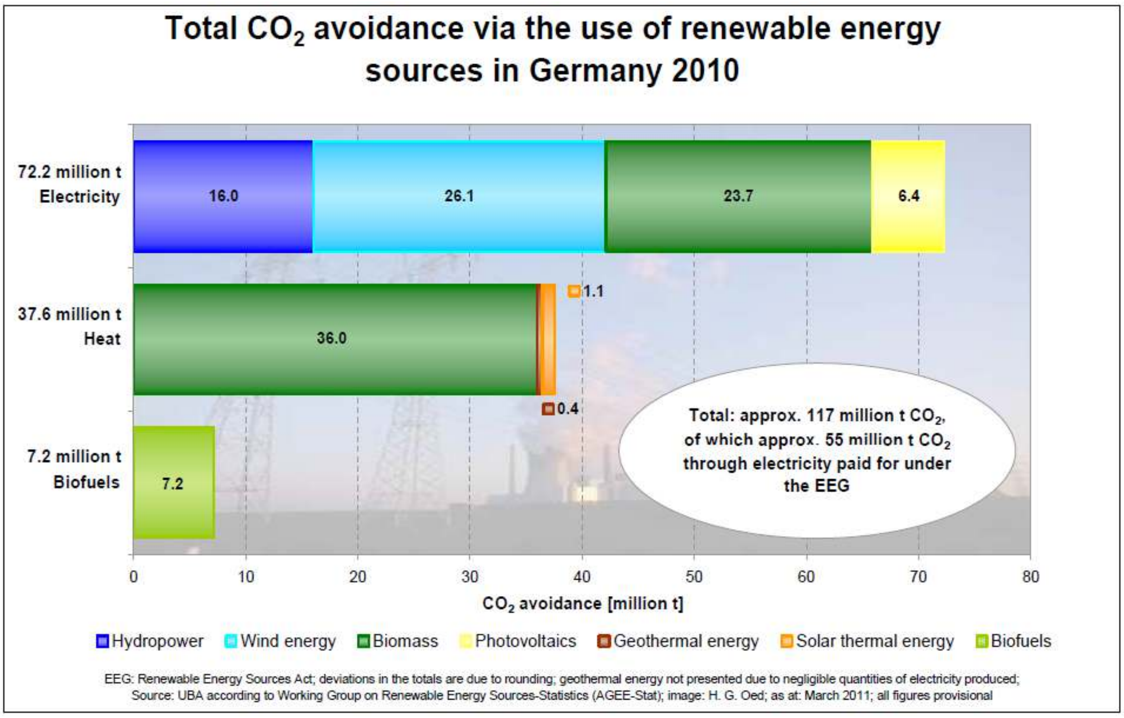
The internet provides several websites, dedicated to PV and renewable energies like:

http://www.bmu.de/english/aktuell/4152.php
http://www.erneuerbare-energien.de/inhalt/39831/39882/
http://en.solarwirtschaft.de
http://www.solarserver.com
http://www.dgs-solar.org/
http://www.solarcontact.de/
http://www.solarfoerderung.de
http://www.eurosolar.de/en/
http://www.top50-solar.de/en
http://www.bine.info/
http://www.dena.de/
http://www.german-renewable-energy.com
http://www.renewables-made-in-germany.com/en/photovoltaics/
http://www.renewablesb2b.com
http://www.gtai.com

BSW represents the German PV and solar thermal industry and supply a lot of market data (http://www.solarwirtschaft.de). The Germany Trade & Invest [5] has the task to acquire foreign enterprises for investments in Germany. This organisation supplies a lot of commercial information and supports investors individually (http://www.gtai.com).

As the result of these long term initiatives, there is a broad awareness and acceptance for renewable energy and PV by the public. In consequence, a constant demand exists for PV products.

Beside these promotion activities, PV industry is an important branch in the technology sector and gains more and more attention in the public.



2.3 PV implementation highlights, major projects, demonstration and field test programmes

Due to the mature PV market in Germany, technical orientated demonstration and large field test activities are not in the centre of interest anymore. The proof that PV works in different kind of applications is done. Therefore, the industry focuses their activities in process optimization to reduce the production cost and to increase the quality of their products. Also recycling was in 2011 interesting.

2.4 Highlights of R&D

Silicon wafer technology

Solar power at significantly lower costs

As part of the so called Photovoltaics Innovation Alliance, the project **SONNE** was launched, coordinated by SolarWorld Innovations with the involvement of 13 companies and 4 research institutions, aiming at significantly improving module efficiency and achieving further cost reductions with crystalline silicon solar cells. The project will focus on cell and module design, appropriate industrial process sequences, the selection of optimum materials, as well as process steps and the requisite technology, plus demonstrator production. BMU has provided 3.4 million euros towards this project.

Simplifying a highly efficient process and making it suitable for industry

Unlike the more widely used practice of p-doping, n-type silicon is doped with elements from a higher main group to achieve greater efficiency. In spring 2011, researchers from Fraunhofer-Institut für Solare Energiesysteme achieved new peak efficiency levels of 23.9 % for solar cells made from n-type silicon in the **Th-ETA** project. The emitter (layer to separate electrical charge carriers) was made from diffused boron on the front, whilst the rear was passivated with a dielectric layer. This exceptional efficiency was achieved thanks to an additional layer of aluminium oxide which improves the solar cell both visually and electrically.

This simplified process has now been adapted for large solar cell surfaces. An industrially manufactured cell with a full-size phosphorous back-surface field achieved an efficiency of 19.6 %. This technique represents an advancement on the current industrial standard, and points to future efficiencies of 20 % or more in industrial production. The Th-ETA project will also develop other cell concepts on different materials and with new structures.

Multi-crystalline versus mono-crystalline

About 90 % of all modules today are based on crystalline silicon, around half of which are mono-crystalline silicon and the other half multi-crystalline silicon. Mono-crystalline material has a uniformly ordered crystalline structure, whilst multi-crystalline silicon is comprised of numerous small crystals ranging in size from a few millimetres to centimetres in a partially ordered crystalline structure. Mono-crystalline cells achieve a superior efficiency of around 19 %, but growing the crystals is more expensive. The industrial technology currently in use only produces an efficiency of 17 % for multi-crystalline cells, but they are cheaper to manufacture.

The joint project **SilKriT** by SolarWorld Innovations GmbH (SWIN) as coordinator, in collaboration with Access e.V. Aachen, aims to narrow the efficiency gap between multi-crystalline and mono-crystalline silicon. SilKriT develops techniques for the production of multi-crystalline block-solidified silicon with the aim of making the partially ordered crystalline structure as uniform as possible. Its project partner Access e.V. uses simulation calculations of the crystallisation and cooling process to estimate the stress distribution and creation of dislocations in the Si block, and endeavours to find process conditions that will significantly reduce the occurrence of dislocations. Process simulations to date have revealed that with standard models, dislocations are produced both during and immediately after crystallisation and during cooling. The smaller the local temperature gradients (or the heat flows linked to them), and the slower the cooling process, the fewer dislocations are created.

In summer 2011, Access e.V. began operation of a laboratory crystallisation furnace which will implement the findings of the model calculations on multi-crystalline silicon blocks in a format of less than 20 kg. For quality control purposes, during the course of the project the blocks produced in the laboratory furnace will be processed into columns and PV wafers at SolarWorld Innovations GmbH, and test solar cells made from them. The idea is to gauge how well the findings will transfer to industrial-scale crystallization plants.

Another research alliance comprised of eleven companies and 13 research institutions has joined forces in the **SolarWinS** project (Solar Research Cluster to Determine the Maximum Level of Efficiency for Multicrystalline Silicon), coordinated by the Freiburg Materials Research Center (FMF) at Albert-Ludwig University and Konstanz University. Since the physical limitations for mono-crystalline silicon are largely known, the research alliance will focus on the efficiency potential of multi-crystalline material. Crystal defects arise during block production (crystallization), on which impurities from the environment accumulate, thus reducing the electrical output. The project aims to minimise the accumulation of impurities and measure the impacts on the material. Computer-assisted models will also be created.

Thin-film technology

Closing the "efficiency gap" between the laboratory and production

Thin-film solar cells demonstrate significant differences in efficiency from the laboratory to production. The joint project **LIST** aims to close this efficiency gap. In a thin-film solar cell, the front contact is comprised of a transparent, conductive layer of metal oxide known as TCO (transparent conductive oxide). In silicon-based thin-film solar cells, this layer plays a key role in light trapping. The rough surface of the TCO allows the light to be scattered and coupled more effectively into the solar cell. If reflectors are additionally used on the rear of the solar cell, the light path can be considerably extended in the silicon absorber layer, which is only a thousandth of a millimetre thick, thus increasing the efficiency of the cell.

Although the TCO materials zinc oxide and tin oxide are already integrated into large-scale solar module production, there is still plenty of scope for development. Loss analyses on industrial production processes indicate that the difference between efficiency levels in the laboratory and in production – often up to 2.5 % – are primarily attributable to the quality of the TCO layer. This potential will be explored by the joint project LIST under the coordination of Forschungszentrum Jülich. Other project partners include Rheinisch-Westfälische Technische Hochschule Aachen, BERLINER GLAS Herbert Kubatz GmbH & Co. KG Syrgenstein, Euroglas GmbH, Fraunhofer-Institute für Schicht- und Oberflächentechnik und für Silicatforschung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Laser Zentrum Hannover e.V., Leybold Optics GmbH, Malibu GmbH & Co. KG, Schüco TF GmbH & Co. KG, Sentech Instruments GmbH and Friedrich-Alexander-Universität Erlangen-Nürnberg. The project will build on a production-scale process in which layers of zinc oxide are applied using the so-called sputtering technique (in which a solid body is bombarded with energy-rich ions) and then wet-etched using liquid chemicals to produce a rough surface. The aim is to improve the quality of the TCO layer, particularly its light scattering properties, using innovative techniques with the hope of boosting the efficiency potential to laboratory level. Above all, the results should be reliably reproducible to allow the efficient transfer to production scale. The BMU has provided 5.7 million euros towards the LIST project.

Test rig measures efficiency of photovoltaic modules

A new measurement station at the test laboratory of TÜV Rheinland, primarily for testing thin-film modules, will enable the analysis of module's electricity yield more accurately in future. The test rig can accommodate modules up to an edge length of 200 cm. It measures spectral sensitivity, i.e. the wavelength range the module is able to use for conversion into electricity, as well as the quantum efficiency and yield of the modules, i.e. the number of electrons that are released per incoming photon. This test rig measures modules within the wavelength range from 300 nm (ultraviolet) to 1,200 nm (infrared) at nanometre increments. Testing is non-destructive, since the module may be contacted to the connection terminals without interfering with the solar cells' circuitry. This saves a considerable amount of time and money when preparing the test samples and during analysis. The measurement station was developed by the Japanese National Institute of Advanced Industrial Science and Technology (AIST) and is one of only a handful of its kind in the world.

Its installation was supported as part of a research project into the long-term stability and performance characterisation of thin-film solar modules carried out by TÜV Rheinland in collaboration with ZSW. The aim of the project is to provide the thin-film PV industry with analysis capacity to accompany development work.

Silicon basis: Combining different approaches for a stable 14 %

Aiming to achieve a stable efficiency of more than 14 % for silicon-based thin-film solar cells (a-si), the Demo14 project by Masdar PV GmbH, Kompetenzzentrum PVcomB at Helmholtz-Zentrum Berlin (HZB), Institut für Energie und Klimaforschung der Forschungszentrum Jülich GmbH (FZJ) and Konrad-Zuse-Zentrums für Informationstechnik Berlin, was set up. The cells developed will form the basis for cost-efficient, industrially manufactured solar modules with stable efficiencies of above 13 %. Until now, the maximum efficiency achieved for modules using solely amorphous silicon is 8 % (Masdar PV), while the efficiency for modules with a layer of amorphous silicon combined with a layer of micro-crystalline silicon, known as tandem cells, is between 8 and 10 %. The project is divided into several phases.

Firstly, the system for plasma-based deposition of the micro-crystalline layers at PVcomB is to be optimised by using all of the multiple process options. Additionally, the project partners are also developing a quantitative mathematical model for predicting the efficiency of new cell concepts as a design and development tool for industrial production. At the same time, the project hopes to gain a better understanding of the materials, especially what happens at the boundary layers, i.e. between the TCO layer of conductive oxides on the front and the layer of amorphous silicon below. Understanding these processes will lead to new developments. Also the possibility of using new highly transparent, highly conductive and stable semi-conductor materials with no reflection losses will be explored. Finally, alternative multi-cell concepts with innovative intermediate and back reflectors are another conceivable option. A mathematical model is being used to analyse these new concepts, and the best ones will be trialled in experiments

CIGS cell: Improving efficiency with computer simulations

Computer simulations can help to find correlations which would simply not be possible with manual research work, due to the amount of time involved. For thin-film solar cells based on the composite semi-conductor CIGS (copper, indium, gallium, selenium or sulphur), for example, efficiencies of above 20.3 % have already been achieved on a laboratory scale, but it has not yet been possible to transfer these high efficiencies to mass production due to an incomplete understanding of the complex correlations involved in this multi-component system. In the **comCIGS** project, the companies IBM Mainz and Schott AG, Johannes Gutenberg University Mainz, Helmholtz Zentrum Berlin für Materialien und Energie and Jena

University have now used computer simulations to identify relevant correlations between the process temperature and efficiency of the CIGS solar cell. These simulated insights into the material's nanostructure have enabled the team to identify an in homogeneity in the material's structure which adversely influences the efficiency of the solar cell and can be avoided with optimised process management. The simulation results indicate that the cell process should be conducted at high temperatures above 600°C and on a suitable high-temperature substrate to allow the homogeneous distribution of indium and gallium. The predicted properties were tested on pilot lines, and the results will now be transferred into mass production.

The research team is also using computer simulations to find a substitute for the current buffer layer, which contains only minimal quantities of cadmium. In future, the modelling will be extended to include boundary layer and diffusion phenomena.

2.5 Public budgets for market stimulation, demonstration / field test programmes and R&D

In Germany, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) takes the responsibility for the renewable energies within the Federal Government.

Last year, the global photovoltaics market continued to grow, albeit far more slowly than in the preceding two years. According to figures supplied by the Swiss bank Sarasin, the newly installed capacity totalled 21 GW worldwide in 2011, corresponding to 3 % year-on-year growth. The same study predicts a 20 % increase in demand for 2012, expected to be based primarily on expansion in the USA, China and Japan; for Europe, demand is predicted to decrease by an average of 3 % per annum until 2015.

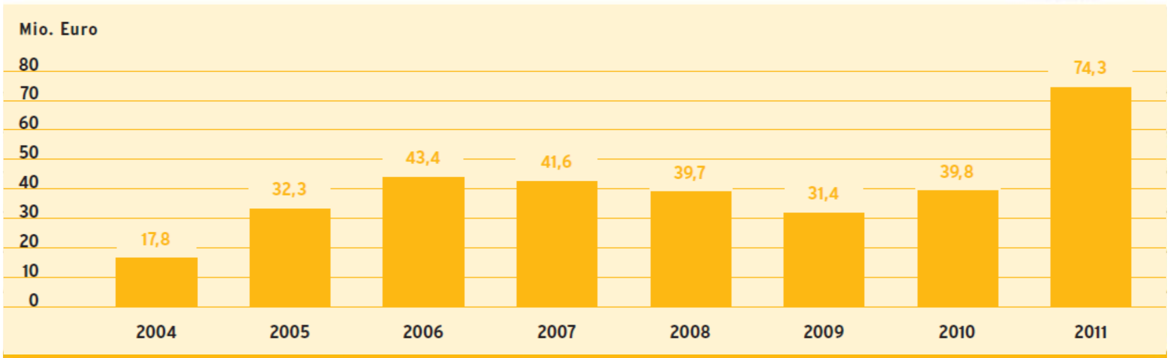
In Germany, according to the Federal Network Agency, new construction in 2011 was roughly on a par with 2010, at approximately 7.4 GW. This meant that by the end of 2011, installed capacity in Germany totalled 24.8 GW. As a result of the amendment to the Renewable Energy Sources Act (EEG) which entered into force in January 2012, and further adjustments during the course of 2012, the annual construction of new photovoltaic installations will flatten out at a lower level, thanks in part to a sharp decrease in the cost of photovoltaic systems. Since 2008, the cost of electricity from photovoltaic installations has halved.

For the German photovoltaic industry 2011 was a challenging year, primarily due to growing competition from Asia. The future looks thorny as well. The global market will no longer continue to grow at its previous rates, and competition will rise further. Additionally, within the EU, there is a pending revision to the electrical scrap directive, from which PV modules have until now been exempt. Under the revision, PV modules will likewise need to be disposed of in suitable collection systems. The German industry association "PV Cycle" offers an initial basis for setting up a compulsory recycling system, but this will create additional costs for companies operating in Europe.

Partly in order to meet this challenge, the Federal Government has created a research mechanism for translating the requisite technical and process innovations more rapidly into production and onto the market with the funding initiative **"Photovoltaics Innovation Alliance**.

In recent years, German research institutions, universities and corporate research departments have made crucial advances in key areas of the technology. Its ability to develop outstanding technology remains one of Germany's core competencies in PV, and consequently, German speakers continue to lead the international conference scene. Furthermore, a forward-thinking educational policy has helped Germany to retain its leading position in terms of the number of scientists, engineers and technical experts in PV.

Source: BMU

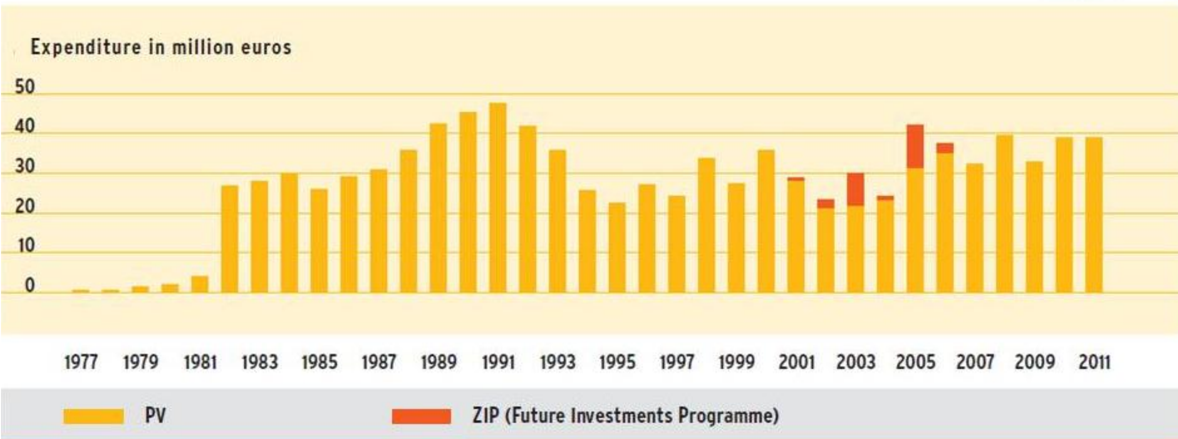


Photovoltaics: developments of new funding approved since 2004

As in the other divisions of technology, in 2011 PV research funding showed a significant upswing, particularly thanks to implementation of the Photovoltaics Innovation Alliance. In 2011, a total of 96 new projects were approved (2010: 45 projects), with a total funding volume of around 74 million Euros, compared with just under 40 million Euros in 2010. In 2011, a total of 39 million Euros was allocated to on-going projects, on a par with the previous year.

In terms of content, BMU research funding priorities are silicon wafer technology, thin-film technologies, systems engineering, alternative solar cell concepts and new research approaches (such as concentrating PV), as well as general issues such as building-integrated photovoltaics, recycling, and accompanying environmental research projects.

Source: BMU



Photovoltaics: annual project funding between 1977 and 2011

The crystalline silicon solar cell continued to command the biggest market share of all solar cell types in 2011. Development progress in this technology, in which the functional core of the solar modules is made of crystalline silicon wafers, is clearly illustrated by a research roadmap prepared by BMU in collaboration with industry in 2005. At that time, the demand for silicon was around 12 g per W, whereas today, this has been reduced to 7 g per W (the roadmap target for 2010 was 10 g). The cell efficiency for multi-crystalline silicon wafers was 14 % in 2005. The roadmap target for 2010 was 18 %, compared with an actual achieved efficiency of up to 19.5 % today.

Among thin-film technologies, the greatest success is the advanced development of CIGS cells (cells made from copper, indium, gallium and selenium), where continuous increases in efficiency have been achieved. In late 2010 Zentrum für Sonnenenergie und Wasserstoff-Forschung Baden-Württemberg (ZSW) reported a world record for laboratory cells of 20.3

%. The first commercial modules are already achieving figures of 14.7 % on the aperture area. Last year, efficiencies of between 12 and 13 % were achieved for industrially manufactured modules. The efficiency target of 14 % by 2010 cited in the BMU research roadmap has since been exceeded. Germany is the world market leader for technology and equipment in CIGS module production. The PV situation in Germany is shaped by two key trends: On the one hand, there is a dynamic market in which German companies are increasingly faced with serious competition. On the other, there is outstanding technical progress, not just at laboratory level, but also in the products manufactured by German companies. BMU's R&D funding aims to support the German PV industry in the face of these conflicting pressures.

At the end of November 2011, a strategy meeting was held in Glottertal near Freiburg im Breisgau to discuss the direction of future research funding, to which the BMU invited selected representatives from the worlds of industry and research. The principal outcomes were that:

- closer collaboration within the German PV industry, as initiated by the PV Innovation Alliance, is desirable, and
- the development "from lab-to-fab" needs to be accelerated, for example by means of platform developments in R&D and via the formation of alliances.

Funding Activities of the BMU

In December 2011, the BMU released a new call for tender which reflects the targets of the new energy research program. Concerning PV, the call addresses five focal points which are all connected to applied research:

- Silicon wafer technology,
- Thin-film technologies, especially based on Silicon and Chalcopyrites (CIS/CIGS),
- System technology for both, decentralised grid-connection and island systems,
- Concentrated Solar Power and other alternative concepts and

Cross-cutting issues like Building Integrated PV (BIPV), recycling or research on the ecological impact of PV systems.

In 2011 the BMU support for R&D projects on PV amounted to about 38.8 MEUR shared by 206 projects in total. That year, 96 (2010: 45) new grants were contracted. The funding for these projects amounts to 74.3 (39.8) MEUR in total. These numbers comprise the BMU funding under the "Innovation Alliance PV" as well, see below.

Details on running R&D projects can be found in the BMU „Annual Report on Research Funding in the Renewable Energies Sector" [7] or via a web-based database owned by PtJ [15]. The German contributions to the PVPS Tasks 11, 12, 13 and 14 are part of the programme.

Funding Activities of the BMBF

In 2008, the BMBF published its concept paper "Basic Energy Research 2020+" aiming for the support of long-term R&D on renewable energies which is complementary to the BMU funding. Concerning PV, currently there are three focal points of engagement:

- A joint initiative of BMBF and industry addresses the development of organic solar cells.
- A call for networks aiming for the development of thin-film solar cells was initiated in 2008. First projects started in 2009, putting emphasis on topics like material sciences including nanotechnology, new experimental or analytical methods and the usage of synergies with other fields of research like microelectronics or bionics.
- Additionally, the BMBF funds the development of the cluster "Solarvalley Mittel-deutschland" as part of the Federal High-Tech Strategy. This cluster comprises most of Germany's PV industry and received federal grants of 40 MEUR from 2009 until 2013.

The BMBF activities will continue under the 6th Energy Research Program.

Innovation Alliance PV – a joint initiative of BMU and BMBF

In summer 2010, BMU and BMBF initiated the Innovation Alliance PV. Under this scheme R&D projects will be funded which support a significant reduction of PV production costs in order to enhance the competitiveness of Germany's industry. Therefore, projects under industrial leadership integrating different steps of the PV value chain were sought. In particular, cooperation between PV industry and PV equipment suppliers is of importance. Together, BMU and BMBF will support this initiative with 100 MEUR. The German PV industry agreed to raise additional 500 MEUR to accompany the Innovation Alliance.

First R&D projects were started in 2011. Currently 19 projects are approved:

- BMU: 9 co-operative projects (38 single grants) with a total amount of funds of 32.6 MEUR.
- BMBF – Basic Research: 5 co-operative projects, total amount of funds: 20.3 MEUR.
- BMBF – Optical Technologies: 5 co-operative projects, total amount of funds: 19.2 MEUR.

Table 3: Public budgets for PV R&D, demonstration/field test programmes and market incentives in Germany 2011.

R&D budget for PV projects by BMU [7]	38,8 Mio. €
R&D budget for PV projects by BMBF [7]	> 17,0 Mio. €
Industrial R&D investments (2008) [1]	163,0 Mio. €

PV feed-in tariff of the EEG from 2011

Date of commissioning	< 30 kWp	up to 100 kWp	up to 1 MWp	> 1MWp
01.01.2011 - 30.06.2011	28,74	27,33	25,86	21,56
01.07.2011 - 31.12.2011	24,43	23,23	21,98	18,33

No feed-in tariff anymore for ground mounted systems on agricultural used fields from 1st of July 2010!

In 2012 the feed-in-tariff will completely restructured and the rates essentially reduced.

3 INDUSTRY AND GROWTH

The German PV industry showed a strong and steady growth in recent years. Today, burdens resulting from the world economic crises and from increased competition result in a far more complex situation. Nevertheless, the foreign trade and inward investment agency of the Federal Republic of Germany "Germany Trade & Invest" lists an impressive number of companies involved in PV:

- 23 inverter manufacturer
- 70 companies with PV productions (ingots, wafer, cells, modules)
- 75 PV equipment manufacturers

and additional manufacturers of materials for PV modules and PV system components [5].

This list shows that the German PV industry is positioned along the whole value chain. During the last years, equipment and production companies became the most experienced ones world-wide. At the end of 2011, around 128 000 workers were employed in the PV industry, in handcraft and trade companies [1].

3.1 **Production** of feedstocks, ingots and wafers

Table 3: Production information for the year for silicon feedstock, ingot and wafer producers in 2011, Germany [2]

Producers	Process & technology	Total Production	Maximum production capacity	Product destination
Silicon feedstock		*t/year*	*t/year*	
Wacker-Chemie	Silicon feedstock	35.000	43.000	market
Joint Solar Silicon GmbH & Co. KG	Silicon feedstock	850	850	Subsidiary
Schmid Silicon	Silicon feedstock	100	180	market
Total		**37.150**	**44030**	
Ingots		*t/year*	*t/year*	
PV Crystalox Silicon GmbH	sc-Si ingots.	**1200**	***1800***	market
Wafer		*MW/year*	*MW/year*	
Bosch Solar Wafers	sc/mc-Si wafers	500	630	market
Conergy	mc-Si wafers	180	200	subsidiary, market
Deutsche Solar AG (Solarworld)	mc-Si wafers	750	1000	subsidiary, market
Sovello AG (ex- EverQ)	mc-Si wafers	180	180	subsidiary
PV Silicon AG	sc-Si wafers	280	350	market
Schott Solar Wafer GmbH	mc-Si wafers	380	480	subsidiary
Total		**2270**	**2840**	

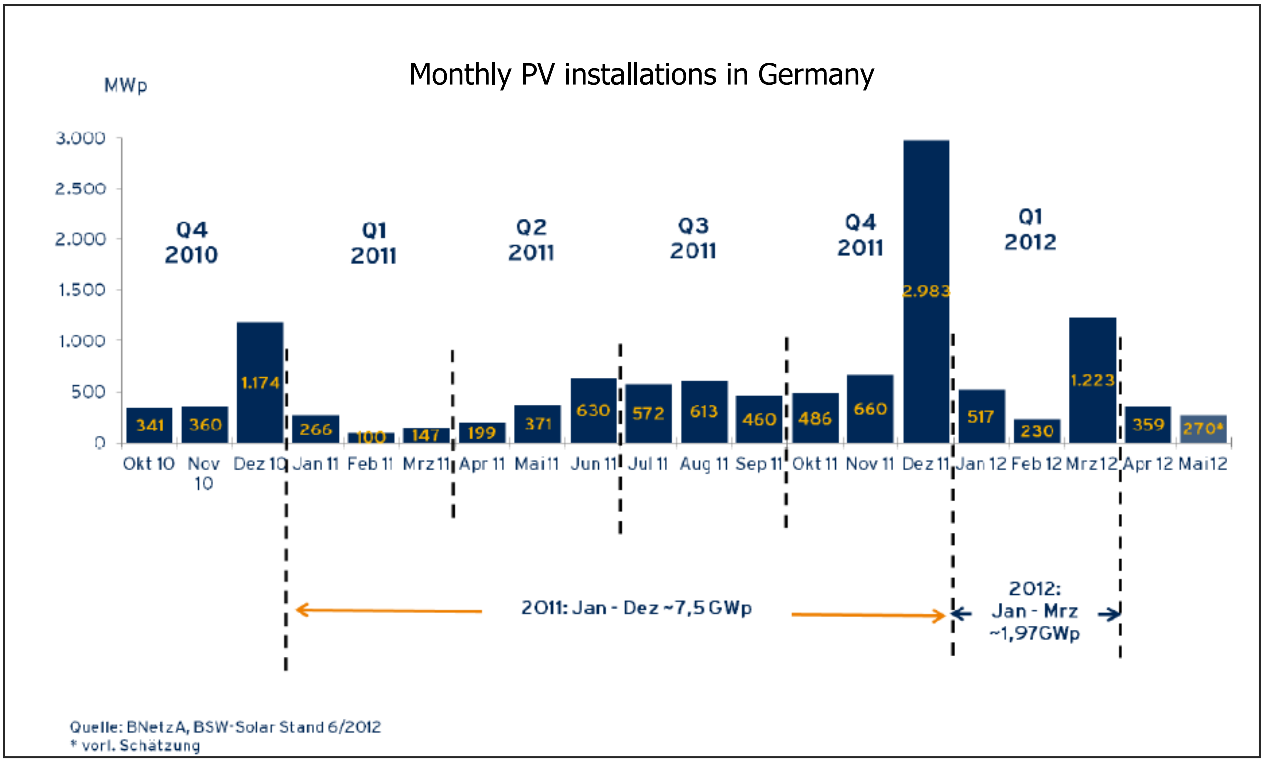
3.2 Production of photovoltaic cells and modules

Table 4: Production and production capacity in Germany for 2011 (Data based on [2]

Technology Type	Production MW	Capacity MW
Si-Module	2302	3472
amorphous Si cells	255,1	401,5
CIS cells	190,1	530
CdTI cells	318	530
CPV cells	5	30
Sum thin-film cells	768,2	1491,5
Si-cells	2151	2661
All cells	**2919,2**	**4152,5**

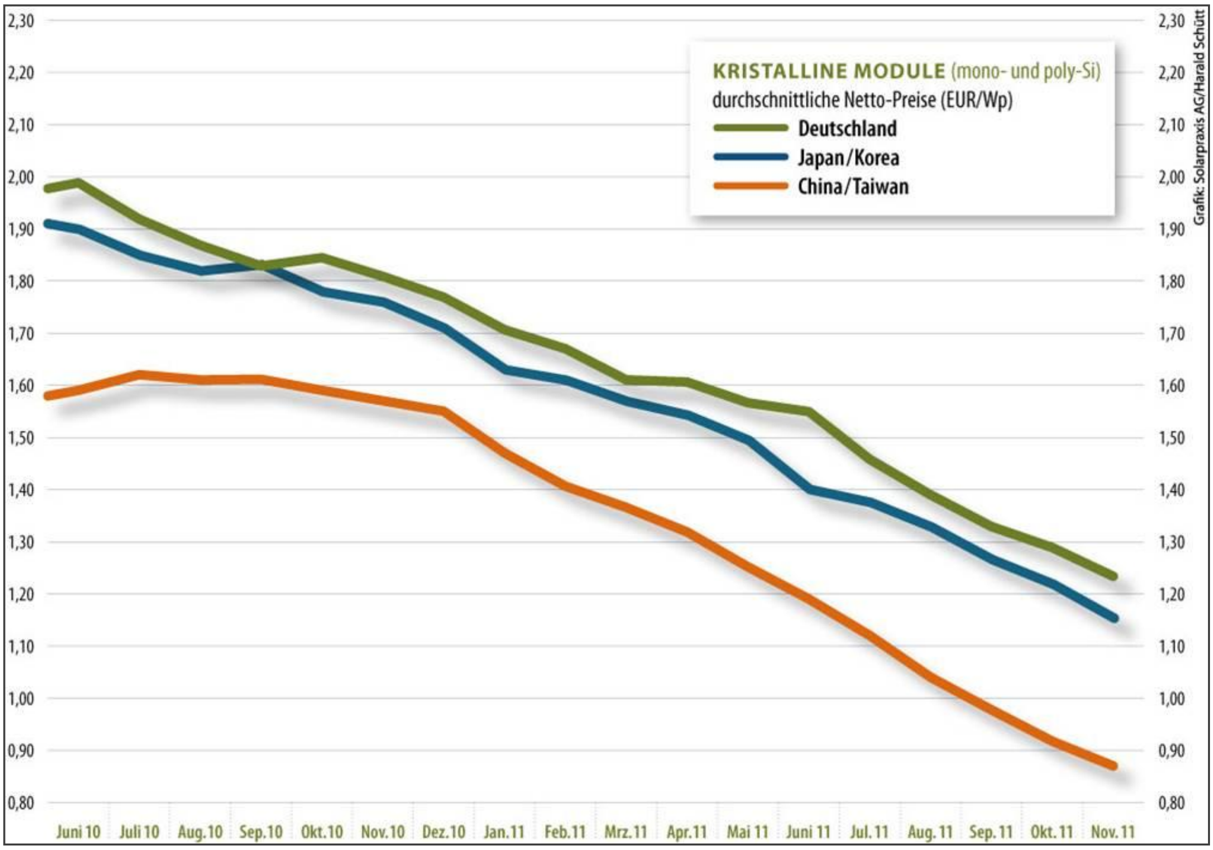
3.3 Module prices

The installation of PV systems in Germany was boosted again in 2011 driven by the Renewable Energy Sources Act (EEG) on the one hand and on the other hand by the decrease of system prices and modules. In 2011 the feed-in tariff was reduced again and the prices of the systems were following. Also the “thread” of further reductions of the FiT for the year 2012 resulted in a hype at the last quarter of 2011.

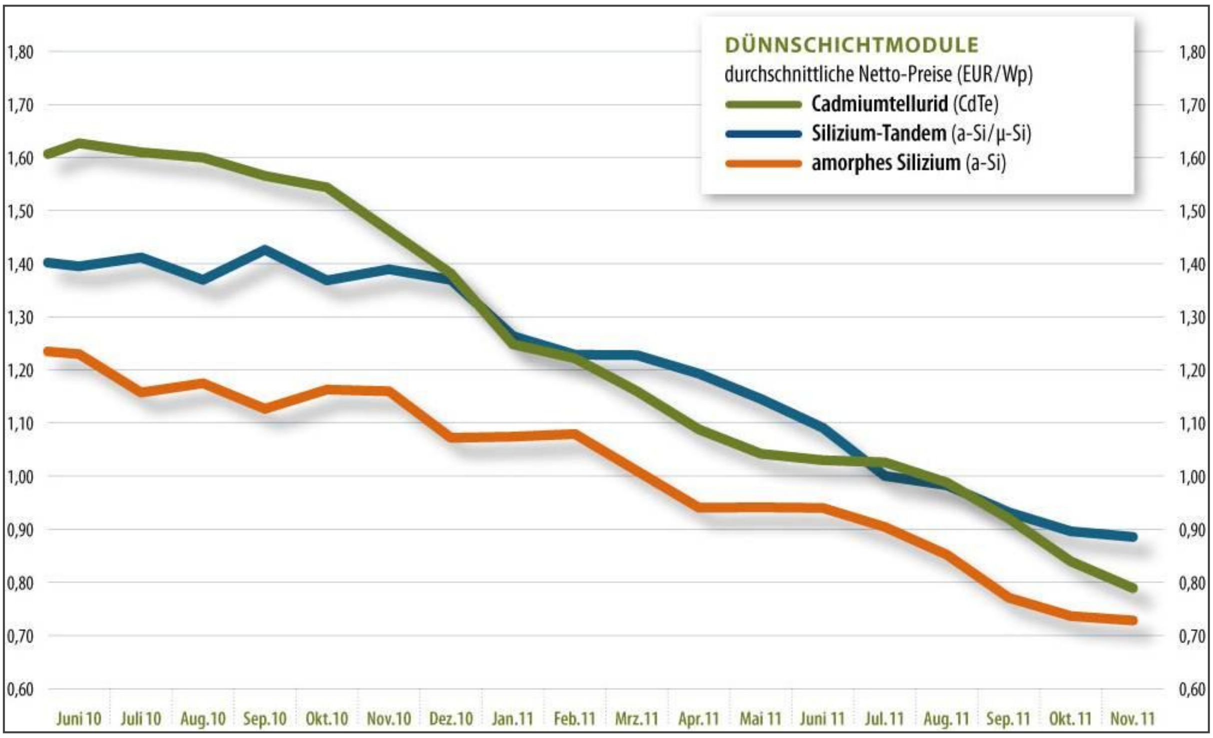


Regarding the development of module prices a distinction must be made between end costumer price and wholesale prices.

Tab. 5a: Average net price of crystalline modules (source Solarpraxis)



Tab. 5b: Average net price of thin film modules (source Solarpraxis)



Tab. 5c: Typical spot market module prices (Dec. 2011, wholesale, VAT excl.) after [6]

Module type, Origin	€ / Wp	Trend from Nov. 2011	Trend from January 2011
Crystalline modules			
Germany	1.12	-4.83 %	-34.40 %
China	0.81	-4.30 %	-44.90 %
Japan	1.10	-3.60 %	-32.52 %
Thin film modules			
CdS/CdTe	0.73	-6.55 %	-41.52 %
a-Si	0.64	-4.88 %	-40.47 %
a-Si/µ-Si	0.82	-3.46 %	-35.10 %

3.4 Manufacturers and suppliers of other components

Due to the well developed PV industry all components for an entire PV system are available in Germany. An excellent overview is given by “Germany Trade and Invest” [5]. For details see the website of the companies.

3.5 System prices

Table 7: Turnkey Prices of Typical PV Applications (19% VAT excluded, net prices rounded, prices at end of 2011, usually grid connected) [11]

1 – 2 kWp: 2.540 €/kWp

2 – 5 kWp: 2.260 €/kWp

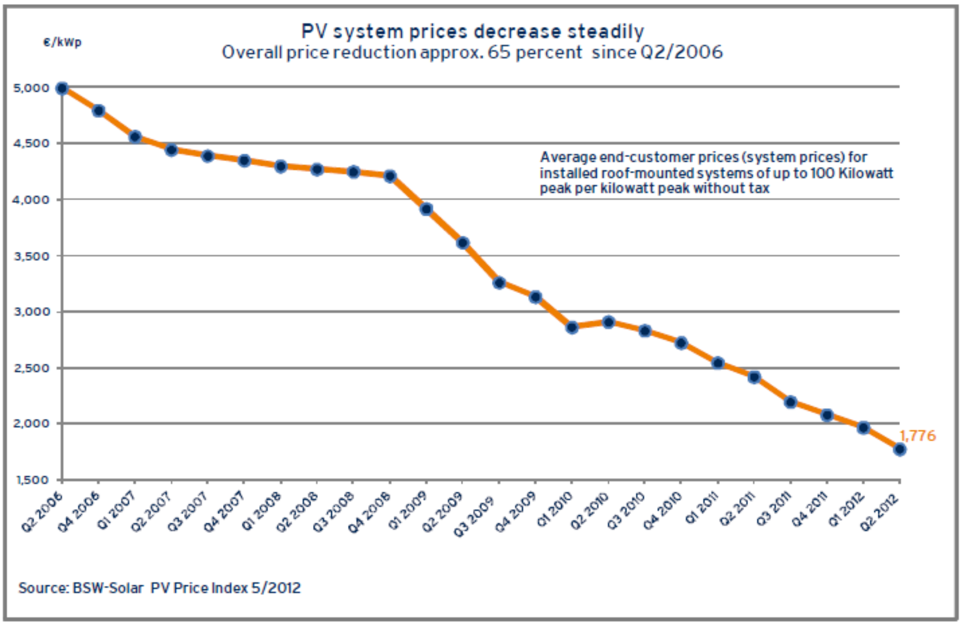
5 - 10 kWp: 2.040 €/kWp

> 10 kWp: 1.790 €/kWp

Table 7a: National trends in system prices (< 10MWp, VAT excl., end of 2011)

Year	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Price €/kW	8 390	6540	6400	5600	5080	5300	5600	5400	5500	4200	3200	2700	2000

The prices are related to roof-top installations and usually the systems are grid-connected in Germany. Less than 10 % of installations are in other categories with specific prices.



	System prices [€/kWp]
Q2 2006	5,000
Q4 2006	4,800
Q1 2007	4,568
Q2 2007	4,448
Q3 2007	4,395
Q4 2007	4,354
Q1 2008	4,303
Q2 2008	4,275
Q3 2008	4,254
Q4 2008	4,216
Q1 2009	3,922
Q2 2009	3,620
Q3 2009	3,263
Q4 2009	3,135
Q1 2010	2,864
Q2 2010	2,912
Q3 2010	2,834
Q4 2010	2,724
Q1 2011	2,546
Q2 2011	2,422
Q3 2011	2,199
Q4 2011	2,082
Q1 2012	1,969
Q2 2012	1,776

3.6 Labour places

The BSW estimates that meanwhile around 10.000 companies with128.000 employees are active in the PV business. More than 200 companies are producer of cells, modules and components.

Table 8: PV-related labour places in 2011 (full time equivalent) [1]

Labour places in total: 128.000

- PV production industry: 22.000
- Component supplier: 30.000
- Machine building Industry: 22.000
- Handicraft: 34.000
- Others: 20.000

Figures for employees in PV institutes are not available.

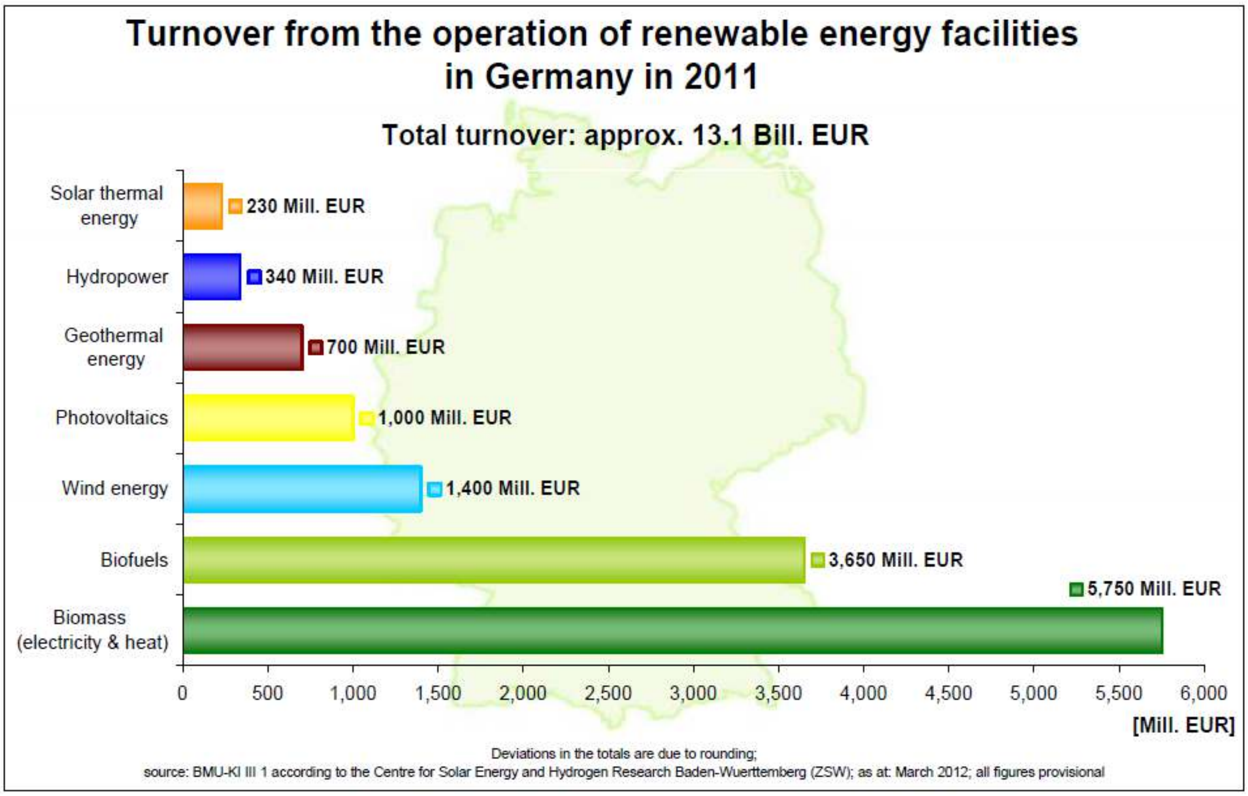
3.7 Business value

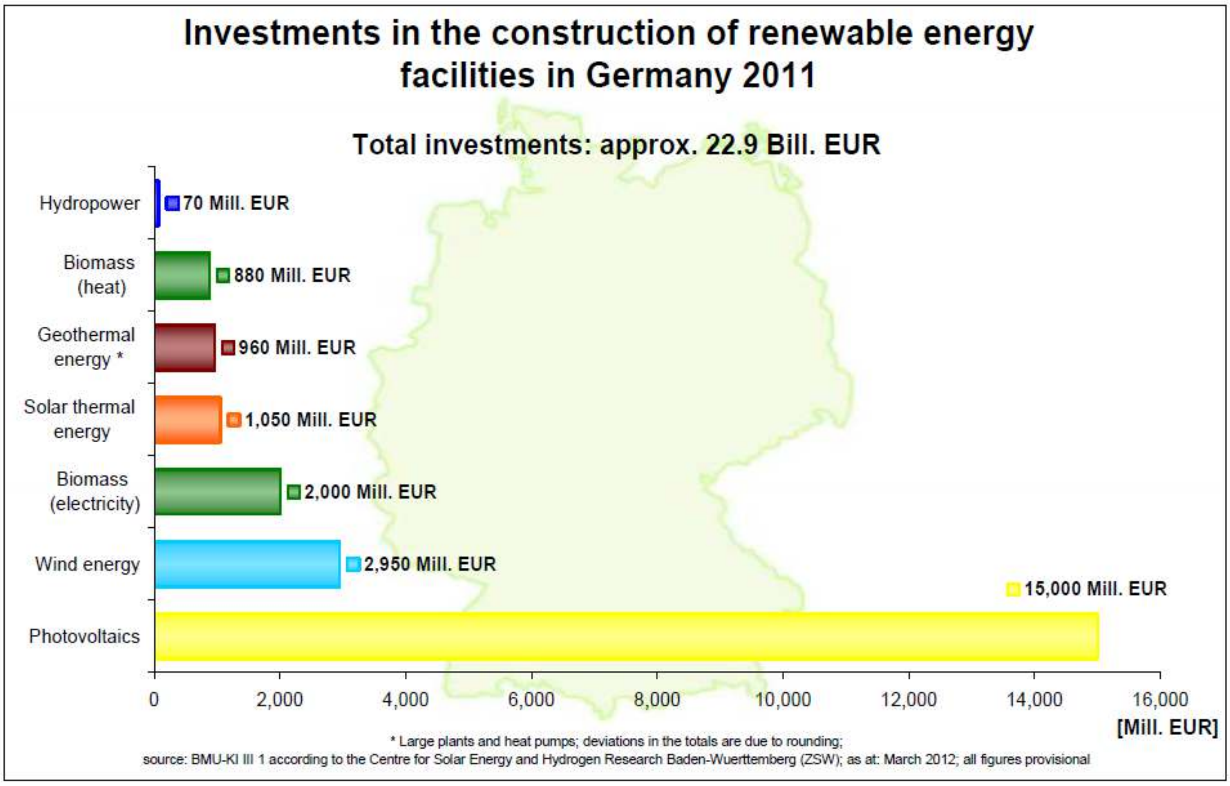
A good overview about the business is given by BSW [1] and AGEE-Stat [3]

Photovoltaic (solar power) industry in Germany — Profile in brief, as of end of 2011 (approx.)

New photovoltaic (PV) capacity installed in Germany 2011	7,500 MWp
Total PV capacity installed in Germany 2011	24,800 MWp
Power generation through PV systems 2011[1]	18,500 GWh
Total number of installed PV systems at the end of 2011	1,090,000
PV share in German gross power consumption 2012[2] / 2020[3]	4% / 10%
CO_2 savings in 2011	12.5 million t
Number of photovoltaic companies (incl. installers and suppliers) of which are producers of cells, modules and other components	10,000 200
Economic benefit of photovoltaics until 2030[3]	56 to 75 billion €
Export quota 2004 / 2011 / 2020[3]	14% / 55% / 80%

[1] internal calculations, preliminary, Source: EEX
[2] forecast, according to ÜNB-Trendszenario
[3] BSW-Solar, according to PV-Roadmap 2020


Turnover from the operation of renewable energy facilities in Germany in 2011
Total turnover: approx. 13.1 Bill. EUR
Solar thermal energy
230 Mill. EUR
Hydropower
340 Mill. EUR
Geothermal energy
700 Mill. EUR
Photovoltaics
1,000 Mill. EUR
Wind energy
1,400 Mill. EUR
Biofuels
3,650 Mill. EUR
Biomass (electricity & heat)
5,750 Mill. EUR
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
5,500
6,000
[Mill. EUR]
Deviations in the totals are due to rounding;
source: BMU-KI III 1 according to the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW); as at: March 2012; all figures provisional


Investments in the construction of renewable energy facilities in Germany 2011
Total investments: approx. 22.9 Bill. EUR
Hydropower
70 Mill. EUR
Biomass (heat)
880 Mill. EUR
Geothermal energy *
960 Mill. EUR
Solar thermal energy
1,050 Mill. EUR
Biomass (electricity)
2,000 Mill. EUR
Wind energy
2,950 Mill. EUR
Photovoltaics
15,000 Mill. EUR
0
2,000
4,000
6,000
8,000
10,000
12,000
14,000
16,000
[Mill. EUR]
* Large plants and heat pumps; deviations in the totals are due to rounding;
source: BMU-KI III 1 according to the Centre for Solar Energy and Hydrogen Research Baden-Wuerttemberg (ZSW); as at: March 2012; all figures provisional

3.8 Framework for deployment (Non-technical factors)

Table 5: PV support measures

	On-going measures	Measures that commenced during 2010
Enhanced feed-in tariffs	Renewable Energy Sources Act (EEG)	Reduction of feed-in tariffs
Capital subsidies for equipment or total cost	Yes, in some states	
Green electricity schemes	Yes, some utilities offer „green electricity“	
PV-specific green electricity schemes	no	
Renewable portfolio standards (RPS)	No obligations for utilities to obtain a minimum percentage of their power from renewable energy resources	
PV requirement in RPS	none	
Investment funds for PV	On commercial basis by banks or investment funds dedicated to renewable energies, particularly large solar power plants	
Income tax credits	None specific for PV, but the regular depreciations by commercial investments	
Net metering	yes	
Net billing	yes	
Commercial bank activities e.g. green mortgages promoting PV	yes	
Electricity utility activities	yes	
Sustainable building requirements	Yes, by law for new buildings, there are provisions for energy efficiency	

3.9 Indirect policy issues

As a result of the dynamic market development grid parity has been reached at the end of 2012. This means that solar power will then be generated at costs corresponding to those of regular consumer electricity tariffs or lower. The **EEG amendment** prepares the way for such a development as it will promote consumers' own consumption to a higher degree: private households that do not feed in solar electricity but consume it themselves will gain up to 8 euro cent per kWh. Businesses will also profit from the amendment as the stipulation will apply to installations with a capacity of up to 500 kW, one hundred times the capacity of a typical single-family home roof installation. This provision on own-consumption will trigger further important technological progress, e.g. in the field of storage technology. Consumption of grid electricity will be reduced, thus easing the burden on the grid. This in turn will advance the integration of electricity generated from renewable energies into the grid.

In contrast to previous EEG stipulations, open space installations will continue to be promoted beyond 1 January 2015. Conversion areas allowing for tariffs pursuant to the EEG will also comprise land converted from residential building or transport use in addition to land converted from agricultural or military use. Open space installations can now also be promoted in a 100 m wide strip along the kerbside of motorways or rail tracks. The category arable land will not apply beyond 1 July 2010. There will be transitional stipulations for open space installations which have already reached an advanced planning stage. [16]

Since the beginning of 2008, additional funding from the auction of emission allowances has been available to the BMU for the implementation of the **Climate Initiative**. The Climate Initiative aims to cost-effectively tap existing potential for emission reductions and advance innovative model projects for climate protection. Trade and industry, local authorities, educational institutions and consumers directly benefit from the numerous actions and support measures. The latest information on the Federal Environment Ministry's Climate Initiative can be found on the BMU website at www.international-climate-initiative.com. The website contains details of the projects and support programmes of the national and international Climate Initiative.

In February 2011 the Federal Cabinet adopted a draft amendment to the **Greenhouse Gas Emissions Trading Act** (TEHG). The amendment to the TEHG transposes comprehensive amendments to the EU Emissions Trading Directive into national law. From 2013 there will be no more free allowances for electricity generation. Power plant operators will have to pay for the emission allowances they need. This does not justify a rise in electricity prices as plant operators have been passing on the price of emission allowances to their customers in full since 2005, even though they received free allowances. From 2013 about five times as many emission allowances will be auctioned in Germany compared to the current trading period (2008-2012). More than 90 percent of the revenues from auctioning will be used for national and international climate protection and measures implementing the energy concept.

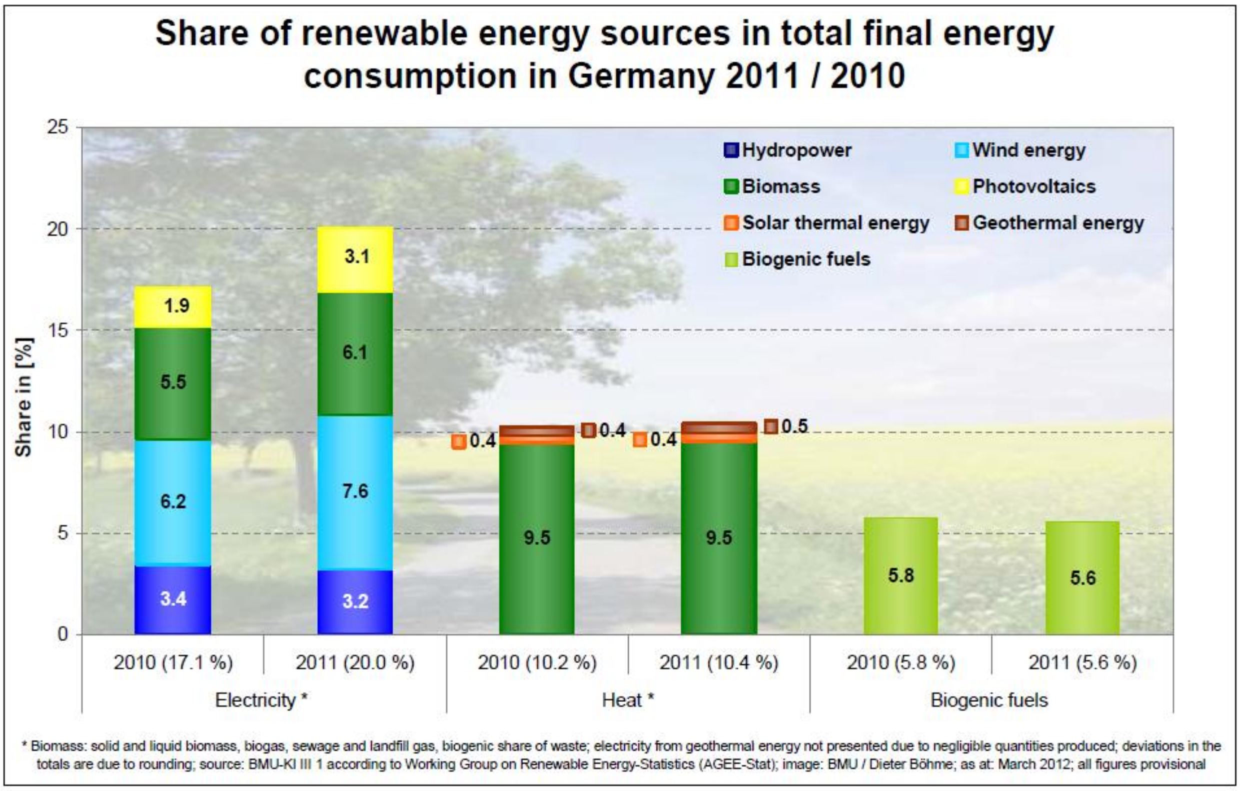
The harmonization of EU emissions trading from 2013 reduces the need for national rules. The amended Greenhouse Gas Emissions Trading Act serves the purpose of incorporating the rules of EU emissions trading into the German legal system and regulating the enforcement of the Act. The competences of the federal and Länder governments regarding the enforcement are defined more clearly than before. For example, in future emissions monitoring will be a responsibility of the German Emissions Trading Authority (DEHSt) at the Federal Environment Agency. This nationwide uniform monitoring of reporting ensures that with regard to emissions trading the same conditions for competition apply to all companies in Germany. [17]

The BMU brochure "**Electricity from Renewable Energy Sources: What does it cost us**" provides the components of the electricity price in Germany, especially for private households and what share do renewable energies cover (http://erneuerbare-energien.de/inhalt/36865/42456/).

Another information about RE-cost is the study "**Cost and benefit effects of renewable energy expansion in the German power and heat market**" (http://www.erneuerbare-energien.de/inhalt/46120/40870/).

Furthermore the website http://www.unendlich-viel-energie.de/en/sun.html supplies a lot of background information about the impact of PV and other RE installations in the German electricity market. Also interesting is the "Brief Analysis on the Current Debate about Costs and Benefits of Expanding the Use of Renewable Energies in Electricity Generation" http://www.unendlich-viel-energie.de/uploads/media/WI_Gutachten_eng_01.pdf.

Germany is member of International Renewable Energy Agency (**IRENA**) and several **IEA** implementing agreements and can promote the use of PV via these institutions. Additionally there are numerous bilateral projects for PV throughout the world.



All in all - politicians, the industry, research and the population have widely accepted the way to more renewable energies in Germany. Therefore a wide range of initiatives, regulations and financial support schemes are existing.

3.10 Interest from electricity utility businesses

Due to the regulations of the EEG there are no real barriers for the development of renewable energy production in general. PV is predominately situated in the private sector and utilities are engaged subordinate, but first initiatives of the utilities are seen in German market in 2012.

4 STANDARDS AND CODES

The elaboration of standards and codes for PV is performed on the European level (CENELEC) and international level (IEC). The actual list of international standards and codes can be found on the web site: www.iec.ch.

ANNEX A: COUNTRY INFORMATION

1) Electricity prices: 0,23 – 0,26 €/kWh + basic fee for households. As an average 0,25 €/kWh is adequate. For industrial supply, the prices are lower depending on consumption. The production cost of conventional power plants are in the range of 8 – 11 €ct/KWh. Tendency to increasing prices in 2011 and 2012. Strong influence by price level of oil and gas.

2) Typical household consumption: 4000 kW/yr.

3) Typical metering and tariff structure: The metering systems are installed in the household. The measurement takes place once a year and a payment in a one or two month period with an invoiced at the end of the year.

4) Average household income: 43.000 €/yr (gross, 2011) (household income can vary by different private status).

5) Typical mortgage interest rate: around 3,0 %/yr

6) Voltage: 230 V / 380 V

7) Electricity Structure: There are parallel structure of large enterprises (E-on, RWE, Vattenfall, EnBW), city owned companies and industrial producers for their own facilities. The grid belongs mostly to the producers.

8) Price of diesel fuel: 1,30 – 1,50 €/l.

9) Typical values for PV system of household: 1- 5 kWp.

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