IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of Photovoltaic Applications in Germany 2017

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

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Participation in IEA PVPS activities on behalf of the
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TABLE OF CONTENTS

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 member countries

The IEA Photovoltaic Power Systems Technology Collaboration 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 participating countries and organisations can be found on the www.iea-pvps.org website.

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 promote and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of PV power systems. Task 1 activities support the broader PVPS objectives: to contribute to cost reduction of PV power applications, to increase awareness of the potential and value of PV power systems, to foster the removal of both technical and non-technical barriers and to enhance technology co-operation. 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 country National Survey Report for the year 2017. 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 INSTALLATION DATA

The PV power systems market is defined as the market of all nationally installed (terrestrial) PV applications with a PV capacity of 40 W or more. A PV system consists of modules, inverters, batteries and all installation and control components for modules, inverters and batteries. Other applications such as small mobile devices are not considered in this report.

For the purposes of this report, **PV installations are included in the 2017 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2017, although commissioning may have taken place at a later date**.

1.1 Applications for Photovoltaics

The vast part of German PV-installations is on-grid, the largest part are building attached systems. Ground mounted systems represent about one third of total installations.

This structure is a direct result of the Renewable Energy Sources Act (EEG 2017 [1]) being the main driving force of the PV market in Germany. It defines the technical (grid access,…) and financial (Feed-In-Tariffs (FiT), Tenders,…) framework for renewable energies. The access to and the level of the FiT depends on size and type (residential, ground mounted, building integrated …) of the system.

In 2015, the government started tenders for ground mounted systems to push this sector to a more market driven competition (see also Chapter 3.3). All tendering calls since then were successful with respect to subscription volume and realisation rates (>90%) and thus revitalized the market for large ground mounted systems.

During the last years, more and more BIPV applications are visible, but still, this market segment plays a minor role compared to ground mounted and rooftop installations. Alternative applications like agricultural PV and VIPV are subject to research projects and start-ups but in most cases they have not yet developed beyond prototype level.

1.2 Development 2017

With installations close to 1,8 GW in 2017, Germany was ranked in place 6 of the largest markets worldwide. Since 2014, yearly installations are constantly increasing from 1,2 GW (2014) to 1,8 GW (2017) with an ongoing positive trend in 2018. The German PV market is a GW market since more than 10 years having reached a total of 42,4 GW by the end of 2017. Subsequently, PV contributed 39,9 TWh, representing 6,8% of the overall electricity production and 7,4% of the consumption. The total amount of electricity generated by grid connected PV systems increased by 4,7 % in comparison to the previous year (see Table 3).

1.3 Total photovoltaic power installed

Since the beginning of 2009 owners of new PV systems are legally obliged to register their systems at the German Federal Network Agency [2]. The data on newly registered systems is published monthly on the website www.bundesnetzagentur.de. Those publications can be regarded as raw data, changes can occur in the following months e.g. due to late registrations. Therefore, this report uses data published by another official source: the “Working Group on Renewable Energy Statistics” (AGEE-Stat) [3] working on behalf of the Federal Ministry of Economic Affairs and Energy (BMWi). This group supplies a wide variety of data for all renewable energies and PV in detail in their yearly report. Still, this data is partly preliminary, slight corrections of numbers can be expected during 1 or 2 years after first publication. Since 2009 AGEE-Stat employs data of the German Federal Network Agency.

Furthermore, the German Solar Association (BSW) supplies data emphasised on the market developments.

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 almost completely connected to the public grid. Therefore, there is only marginal need for these systems (parking meters, remote relay transmitters,…) and regarding the total installed capacity of PV, these systems are negligible, estimated less than 1 ‰ compared to grid connected PV capacities and will not be mentioned in this report anymore.

Table 1: PV power installed during calendar year 2017 [2]

AC			**MW installed in 2017**	**MW installed in 2017**	**AC or DC**
Grid-connected	BAPV	Residential (<= 10kW)	1299	461	DC
		Commercial (>10 to 250 kW)		463	DC
		Industrial (>250 kW)		375	DC
	BIPV	Included in BAPV Data			
	Utility-scale	Ground-mounted	477		DC
Off-grid		Residential (SHS) Other Hybrid systems	0[1]		
		Total	1776		

[1] There is no official data source for off-grid installations. It can be assumed, that the number of Off-grid installations in Germany is negligible.

Table 2: Data collection process:

Is the collection process done by an official body or a private company/Association?	Public body
Link to official statistics (if this exists)	www.bundesnetzagentur.de (German Federal Network Agency [2]) www.erneuerbare-energien.de ("Working Group on Renewable Energy Statistics" AGEE-Stat [3])
Data collection process	All grid connected PV systems have to be registered to the Bundesnetzagentur. Due to the official registration procedure by German Federal Network Agency the accuracy of these data can be assumed better than ± 1 %.

Table 3: PV power and the broader national energy market.

MW-GW for capacities and GWh-TWh for energy	2017 (all preliminary)	2016	2015
Total power generation capacities (all technologies)	218,1 GW [4] [5]	212,0 GW [4]	204,9 GW [4]
Total power generation capacities (renewables including hydropower)	113,4 GW [4] [5]	104,5 GW [4]	97,7 GW [4]
Total electricity demand (= consumption)	N/A	541,1 TWh [4]	538,6 TWh [6]
Total electricity production	N/A	590,4 TWh [4]	584,6 TWh [6]
Total primary energy Consumption	13.500 PJ [3]	13.383 PJ [3]	13.306 PJ [3]
New power generation capacities installed during the year (all technologies)	6,1 GW [5][2]	7,2 GW [4]	8,3 GW [6]
New power generation capacities installed during the year (renewables including hydropower)	8,9 GW [5]	6,7 GW [4]	7,6 GW [6]
Total PV electricity production in GWh-TWh	39,895 TWh [3]	38,098 TWh [3]	38,726 TWh [3]
Total PV electricity production as a % of total electricity consumption	7,4 %[3]	7,0 %	7,2 %
Total PV electricity production as a % of total electricity production	6,8 %[4]	6,5 %	6,6 %

[2] Main contributions: Renewables (+8,9 GW), Hard coal (-2,4 GW)

[3] With respect to the electricity consumption of 2016

[4] With respect to the electricity production of 2016

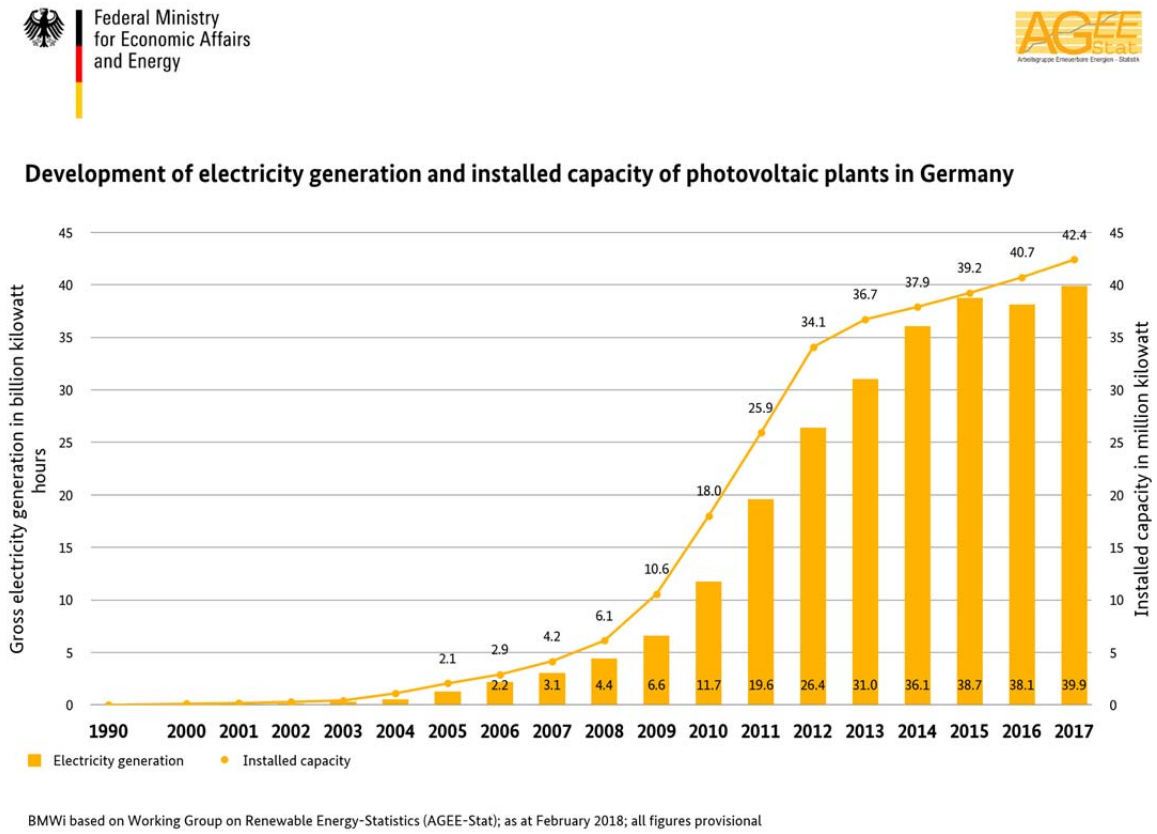
Table 4: Other information

	2017
Number of PV systems in operation	1,64 Mio [7]
Capacity of decommissioned PV systems during the year in MW	N/A
Total capacity connected to the low voltage distribution grid in MW	24.101 MW (2016) [8]
Total capacity connected to the medium voltage distribution grid in MW	14.281 MW (2016) [8]
Total capacity connected to the high voltage transmission grid in MW	2.334 MW (2016) [8]

Table 5: History of cumulative installations 1990-2016 [3]

Year	Cumulative installed power [GW]	**Year**	Cumulative installed power [GW]
1990	0,002	2008	6,1
1995	0,018	2009	10,6
2000	0,114	2010	18,0
2001	0,176	2011	25,9
2002	0,296	2012	34,1
2003	0,435	2013	36,7
2004	1,1	2014	37,9
2005	2,1	2015	39,2
2006	2,9	2016	40,7
2007	4,2	2017	42,4

Figure 1: Development of electricity generation and installed capacity [3]



2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 4 shows the module prices (crystalline silicon) on the European spot market from 2010 to 2017, the prices represent average prices of December of the corresponding year. During the years 2010 to 2016, averages were determined for different module origins (Germany, China, Japan/Korea, Southeast-Asia/Taiwan), in 2017, the breakdown was done by different quality levels: “High Efficiency”, “All Black”, and “Mainstream”. End-customer prices for an average turnkey PV system can be estimated a factor 2,5 to 4 higher [9].

During 2017, the average price for High Efficiency modules dropped by 10,7%, for Mainstream modules by 13,6%. Compared to that, the price decay for All Black modules remained relatively small (3,9%).

Table 4: Typical module prices for a number of years. European spot market prices [€/Wp]. [9]

Year	2010	2011	2012	2013	2014	2015	2016	2017
Standard module crystalline silicon price(s) €/Wp	1,55-1,77	0,81-1,12	0,54-0,84	0,52-0,70	0,45-0,62	0,47-0,64	0,41-0,57	0,38-0,50

2.2 System prices

Table 5 gives an overview over system prices in different system categories. The prices must be understood as the typical range, individual prices can over- or underrun the given values. Investments in PV installations are attractive even without financial support by a Feed-in-Tariff. Since 2006, system prices have been reduced by 13 % in the yearly average and accordingly around 75 % in total. A PV rooftop system in the range of 10 – 100 kW cost about 1 100 EUR/kW (average) in 2016 [10]. The Levelized Costs of Energy (LCOE) for such a PV system are around 0,11 EUR/kWh whereas the average electricity price for a private household is around 0,30 EUR/kWh (including VAT, 1st of April 2017) [4].

Table 5: **Turnkey Prices of Typical Applications, 2017[5] [11]**

Category/Size	Typical applications and brief details	Current prices per €/kWp
Grid-connected Rooftop up to 3 kW	Small rooftop systems, mostly for private use, significant share of self-consumption.	min 1.125 avg 1.520 max 1.980
Grid-connected Rooftop from 3 to 10 kW	Rooftop systems, mostly for private use, significant share of self-consumption.	min 1.035 avg 1.310 max 1.575
Grid-connected Rooftop from 10 to 100 kW	Large rooftop systems: agricultural or industrial buildings, predominantly for grid injection	min 855 avg 1105 max 1.350
Grid connected ~300 kW		avg 975
Grid connected Ground mounted ~1000 kW		avg 915
Grid-connected Ground-mounted above 1 MW	Ground mounted systems can only be funded if they go through a tendering procedure. The results of the tenders lead to the conclusions, that system prices in this category can reach values around 0,5-0,6 €/Wp	500 - 600

2.3 Financial parameters and specific financing programs

Residential systems

For financing renewable energy systems, the government-owned development bank KfW (Kreditanstalt für Wiederaufbau – Reconstruction Credit Institute) offers – under certain conditions – a loan interest rate of 1 %. The maximum credit amount is 50.000 €. In the private sector, several

[5] Prices are estimated on the base of a survey in the 1st quarter of 2016. The average price decay since then was assumed to be in the order of 10% as reported in [10] for rooftop systems of 10 to 100 kW.

banks offer specific loans for PV-installations. The interest rates depend on the actual conditions but usually are higher than the KfW rate.

2.4 Additional country information

Table 6: Country information

Retail electricity prices for a household (2.500-5.000 kWh/year, incl. VAT)[€ct/kWh] [4]	29,86
Retail electricity prices for a commercial company (50MWh/year, excl. VAT)[€ct/kWh] [4]	21,70
Retail electricity prices for an industrial company (24 GWh, excl. VAT) [€ct/kWh] [4]	14,90
Population (30.09.2017) [12]	82.740.900
Country size [km^2]	357.375
Global solar irradiation (2016) [kWh/m^2] [13]	min 895 avg 1.078 max 1.372
Average PV yield (according to the current PV development in the country) [kWh/kWp]	960 (average 2017) 1.050 (expected average under best operation conditions)
Name and market share of major electric utilities (2016) [14]	RWE (33,5 %) Vattenfall (17,1 %) EnBW (12,1 %) E.ON/Uniper (9,4 %) LEAG (4,4%)

3 POLICY FRAMEWORK

This chapter describes the support policies aiming directly or indirectly to drive the development of PV. Direct support policies have a direct influence on PV development by incentivizing or simplifying or defining adequate policies. Indirect support policies change the regulatory environment in a way that can push PV development.

The "Energiewende", the transformation of the energy system is a core task for Germany's environmental and economic policy. The overall objective is an environmental friendly, reliable and economical feasible energy supply. The German Federal Government paved the way for this target when announcing the German Energy Concept in autumn 2010 [15]. Moreover, it was decided to terminate the production of nuclear power until 2022. Therefore, the Federal Ministry for Economic Affairs and Energy (BMWi) defined an energy agenda comprising 10 key projects to approach this goal of the energy transition during the 18th legislative term (2013-2017) [16].
The goals are to be reached firstly by efficient energy use and secondly by the use of renewable energies. The German Energy Concept states that renewable energies will contribute the major share to the energy mix of the future. The aim of the German Energy Concept is to reach 18 % of the total gross energy consumption in 2020 (in 2016, 14,8 % were reached [3]). Beyond that with respect to the electricity supply, the share for renewable energies shall reach 35 % in 2020, 40-45 % in 2025 and 80 % in 2050. With respect to the electricity supply, the share for renewable energies has reached approx. 36,2 % (2016: 31,6 %) [3] of the gross electricity consumption of Germany in 2017.

Photovoltaic reached a share of 6,8 % of gross electricity production (7,4% of electricity consumption) and thus is a major part of this development driven by the Renewable Energy Sources Act (EEG 2017 [1]) on the one hand and a noticeable decrease of system prices on the other hand.

In order to streamline the German energy policies, the responsibility for all energy related activities are concentrated within the Federal Ministry for Economic Affairs and Energy (BMWi).

3.1 Direct support policies for PV installations: New, existing or phased out measures in 2017

3.1.1 Description of support measures excluding BIPV, and rural electrification

In terms of achieving expansion targets for renewable energies in the electricity sector, the Renewable Energy Sources Act 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 (FiT) for them. Due to the successful but very fast increase in PV and wind energy generation, and in order to stimulate competition, additional amendments to the EEG have been introduced from August 1st 2014 on.

During the last and coming years, the funding changes stepwise from a classic FiT Model more and more to market driven models. In 2017 there were 3 different models active:

- Classic FiT: System owners could choose this model for systems < 100 kWp on residential or non residential (lower FiT) Buildings, the FiT depends on the system size. All FiT-rates are guaranteed for an operation period of 20 years. It includes a monthly adapted degression rate of the FiT, which depends on the previously installed PV capacity ("breathing FiT", see Table 8).
- Market integration model: This model can be used for systems on residential or non-residential (lower FiT) buildings up to 750 kWp. The electricity is sold on the market, a

feed-in premium (calculated as the difference between average market price and corresponding FiT) is paid to the electricity producer on top.

- Tenders: For all systems not matching to the limitations of the FiT models (mainly ground mounted systems and systems > 750 kWp) there were three calls for tenders: see Chapter 3.3

The procedure of "breathing FiT" tends to stimulate a yearly installation of 2,5 GW [1]. While the FiT was kept stable during 2016, it was reduced by approx. 0,75% (three times 0,25%) during 2017 due to growing installation numbers.

The FiT system terminates at a total installed PV capacity of 52 GW, the government is obliged to present a new support system well before. Meanwhile, the EEG contains measures for the integration of PV systems into the grid management.

Since 2014, owners of a newly installed system > 10 kWp have to pay a reduced rate of 30 % of the EEG-surcharge (see also Chapter 3.4) for every self-consumed kWh. In 2017 the rate will increase to 40 %. Owners of systems below 10 kWp are not affected.

Table 7: Overview: Feed in Tariffs for different system types [2]

Classic Feed in Tariff

System type	Systems on residential rooftops and noise protection walls			Systems on non residential buildings
System size [kWp]	< 10	10 - 40	40 - 100	< 100
FiT Jan 2017 [€ct]	12,30	11,96	10,69	8,51
FiT Dec 2017 [€ct]	12,20	11,87	10,61	8,44

Market integration model

System type	Systems on residential rooftops and noise protection walls			Systems on non residential buildings
System size [kWp]	< 10	10 - 40	40 - 750	< 750
FiT Jan 2017 [€ct]	12,70	12,36	11,09	8,91
FiT Dec 2017 [€ct]	12,60	12,27	11,01	8,84

Tenders for ground mounted systems

	1st call	2nd call	3rd call
Contracted tariffs 2015 [€ct]	8,48 - 9,42	8,49	8,0
Contracted tariffs 2016 [€ct]	6,94 - 7,68	6,80 - N/A	6,26 - 7,17
Contracted tariffs 2017 [€ct]	6,00 – 6,75	5,34 – 5,90	4,29 – 5,06

Table 8: Monthly degression of the feed-in Tariff.

Installations during the last 6 months, projected to 1 year [GWp]	Monthly change of FiT [%]
> 7,5	-2,8
6,5 - 7,5	-2,5
5,5 - 6,5	-2,2
4,5 - 5,5	-1,8
3,5 - 4,5	-1,4
2,5 – 3,5	-1,0
2,3 - 2,5	-0,5
2,1 - 2,3	-0,25
1,7 - 2,1	0
1,3 - 1,7	+1,5 (per quarter)
< 1,3	+3,0 (per quarter)

3.1.2 BIPV development measures

There were no special measures favouring the development of PV as building element in Germany in 2017.

3.1.3 Support for electricity storage and demand response measures

Since 2013 the KfW (see also Chapter 2.3) is running a market stimulation program to boost the installation of local stationary storage systems in conjunction with small PV systems < 30 kWp. The funding is two-fold: A loan and a grant on the repayment. The first phase ended in 2015 and was limited to a total of 25 MEUR of grants. A second phase is active from 2016 until end of 2018 with a funding volume of 10 MEUR (grants) per year.

During 2017, the installation of a storage system was funded for 6.954 storage systems (564 for existing and 6.390 for newly installed PV systems), with the total volume of loans reaching 123 MEUR.

During the first phase (2013-2015), more than 17.000 storage systems were funded. [17] [18]

Table 9: PV support measures (summary table)

	On-going measures residential	Measures that commenced during 2016 - residential	On-going measures Commercial + industrial	Measures that commenced during 2016 – commercial + industrial	On-going measures Ground-mounted	Measures that commenced during 2016 – ground mounted
Feed-in tariffs	yes	-	yes	-	-	Only after a tender
Feed-in premium (above market price)	yes	-	yes	-	yes	-
Self-consumption	yes	-	yes	-	yes	-
Net-metering	-	-	-	-	-	-
Net-billing	-	-	-	-	-	-
Sustainable building requirements		-		-		-
BIPV incentives	-	-	-	-	-	-

3.2 Self-consumption measures

Table 10 gives an overview of the current situation regarding self-consumption in Germany. In general, self-consumption is pushed forward during the last years due to several reasons. Main reasons are the continuous degression of FiT (making self-consumption financially attractive), the decreasing prices of storage systems (leading the possibility of higher self-consumption) and regulatory measures like the limitation of the grid injection to 70 %.

Table 10: Self-consumption Schemes

PV self-consumption	1	Right to self-consume	Yes
	2	Revenues from self-consumed PV	Savings on the electricity bill.
	3	Charges to finance transmission & distribution grids	For systems > 10 kWp, the "EEG surcharge" (see Chapter 3.4) has to be payed on self consumed electricity.
Excess PV electricity	4	Revenues from excess PV electricity injected into the grid	FiT (see Chapter 3.1)
	5	Maximum timeframe for compensation of fluxes	Real time
	6	Geographical compensation	On site only
Other characteristics	7	Regulatory scheme duration	20 years (FiT)
	8	Third party ownership accepted	All
	9	Grid codes and/or additional taxes/fees impacting the revenues of the prosumer	Grid codes compliance and partial EEG surcharge (for systems >10 kWp)
	10	Regulations on enablers of self-consumption (storage, DSM…)	Battery storage incentives
	11	PV system size limitations	Minimum 10 % of self-consumption
	12	Electricity system limitations	52 GW of PV installations
	13	Additional features	Systems >10 kWp must be either remotely controllable by network operator or need to limit grid injection to 70 % of maximum power.

3.3 Tenders, auctions & similar schemes

Since 2015, within the "market integration model" three auctions per year take place for ground-mounted photovoltaic installations. The aim of the auctions for ground-mounted PV installations is to achieve the expansion targets for renewables in a cost-efficient manner, especially pushing market price oriented financing models. The three calls in 2017 covered a capacity of 600 MW altogether.
As shown in Table 11, the proposed capacity was in all calls significantly over-subscribed and the price level was reduced from call to call.

Table 11: Calls for ground-mounted systems (overview 2015-2017) [2]

Call Deadline	Apr 15	Aug 15	Dec 15	Apr 16	Aug 16	Dec 16	Feb 17	Jun 17	Okt 17
	Pay-as-bid	Uniform pricing	Uniform pricing	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid	Pay-as-bid
Volume [MW]	150	150	200	125	125	160	200	200	200
Bids	170	136	127	108	62	76	97	133	110
Total volume of bids [MW]	715	558	562	539	311	423	488	646	754
Accepted bids	25	33	43	21	22	27	38	32	20
Accepted volume [MW]	157	159	204	128	118	163	200	201	222
Average price [€ct/kWh]	9,17	8,49	8,00	7,41	7,25	6,90	6,58	5,66	4,91
Commissioning deadline	May 17	Aug 17	Dec 17	Apr 18	Aug 18	Dec 18	Feb 19	Jun 19	Oct 19

3.4 Financing and cost of support measures

The direct costs of the energy transition to renewables are compensated by the so called EEG-levy, paid by the electricity consumers. In 2017 the EEG-levy amounted to 6,88 €ct/kWh (2016: 6,35 €ct/kWh, 2018: 6,79 €ct/kWh). There are special treatments for energy intensive industries. [19]

4 INDUSTRY

4.1 Production of feedstocks, ingots and wafers (crystalline silicon industry)

The production capacity of the three main suppliers of silicon feedstock - Schmid Polysilicon Production GmbH, Silicon Products Group and Wacker Chemie AG – is shown in Table 12 [20], [21]. The production of Wacker Chemie AG includes the production location Burghausen and Nünchritz (both Germany) and Charleston (USA).

Additionally, there is a production capacity of SolarWorld AG (Germany) in the range of 250 MW for multi-Si ingots and 500 MW for mono-Si ingots [22]. Remark: Solarworld AG announced their insolvency in May 2017.

Table 12: Production information for the year for silicon feedstock

Manufacturers (or total national production)	Process & technology	Total production [t]
Schmidt Polysilicon Production GmbH	Silicon feedstock	180 (in 2016)
Silicon Products Group	Silicon feedstock	1.800 (in 2016)
Wacker Chemie AG	Silicon feedstock	>70.000

4.2 Production of photovoltaic cells and modules (including TF[6] and CPV[7])

Total PV cell and module manufacture together with production capacity information is summarised in Table 13 and Table 14 below. Please note, the data is from 2016. There is no updated data available.

Table 13: Production and production capacity information of solar cell manufacturer in 2016 [20]

Cell manufacturer	Location	Production capacity [MWp]	Employees
aleo sunrise GmbH	Prenzlau	100	n/a
Bluecell GmbH[8]	Arnstadt	100	84
Solar World AG[9]	Arnstadt	700	> 250
Solar World AG[8]	Freiberg	330	> 250

[6] Thin Film: CIGS, CdTe, OPV

[7] Concentrating PV, predominantly based on highly efficient III-V-multiple junction cells

[8] Insolvency 06/2017

[9] Insolvency 05/2017

Table 14: Production and production capacity information of module manufacturer in 2016 [20]

Module manufacturer	Location	Technology	Production capacity [MWp]	Employees
aleo solar GmbH	Prenzlau	Si	320	n/a
ALGATEC Solarwerke Brandenburg GmbH	Prösen, Großräschen	Si	25	< 50
asalo Technologies GmbH (TUSAI Holding)	Erfurt	Si	40	<50
Astronergy Solar Module GmbH	Frankfurt (Oder)	Si	300	n/a
Axitec Energy GmbH & Co, KG	Böblingen	Si	300	<50
AxSun Solar Energy GmbH & Co. KG	Laupheim-Baustetten	Si	70	n/a
CS Wismar GmbH (Sonnenstromfabrik)	Wismar	Si	525	n/a
GSS Gebäude-Solarsysteme GmbH	Korbußen	Si	20	<50
Heckert Solar GmbH	Chemnitz	Si	300	51-250
Hörmann Novo Solar GmbH	Laubusch	Si	10	<50
ML&S GmbH	Greifswald	Si	200	n/a
SI Module GmbH	Freiburg	Si	25	< 50
Solarfabrik CL GmbH	Freiburg	Si	n/a	< 50
Solarnove GmbH	Wedel	Si	35	< 50
Solarwatt GmbH	Dresden	Si	250	51-250
Soluxtec GmbH	Bitburg	Si	n/a	< 50
Sunset Solar GmbH & Co. KG	Löbichau	Si	40	< 50
Sunware Solartechnik GmbH & Co. KG	Duisburg	Si	n/a	< 50
Solarworld AG[9]	Arnstadt	Si	200	> 250
Solarworld AG[9]	Freiberg	Si	660	> 250
Avancis GmbH (CNBM international)	Torgau	CIGS	100	> 250
Manz CIGS Technology GmbH (NICE)	Schwäbisch Hall	CIGS	5 - 10	150
Solibro GmbH (Hanergy)	Bitterfeld-Wolfen	CIGS	120	n/a
Calyxo GmbH (Solar Fields LLC)	Bitterfeld-Wolfen	CdTe	85	51 - 250
Azur Space Solar Power GmbH	Heilbronn	GaAs	n/a	51-250
Heliatek GmbH	Dresden	OPV	R&D	n/a

4.3 Manufacturers and suppliers of other components

Balance of system component manufacture and supply is an important part of the PV system value chain. Table 15 shows German manufacturers of inverters (data from 2013). There are several other system components suppliers (e.g. cables, connectors, tracking and mounting systems) listed in [20].

Table 15: Overview of balance of system component manufacturers [20]

	Company	Location	Capacity 2012 [MWp]	Employees at respective location
Inverters	AEG Power Solutions	Warstein-Belecke	n/a	680
	Bonfiglio Vectron	Krefeld	n/a	112
	Converteam	Berlin	n/a	700
	Diehl AKO	Wangen	700	140
	Dorfmüller Solaranlagen	Kernen	5	5
	Enecsys Europe	Bad Homburg	n/a	6
	FEG	Sömmerda	< 1	11
	Ingeteam	Hamburg, München	2.000	350
	KACO new energy	Neckarsulm	1.200	400
	KOSTAL Industrie Elektrik	Hagen	n/a	190
	LTi REEnergy	Unna	500	250
	M+W Group	Crailsheim	100	50
	PCS Power Converter Solutions GmbH	Berlin	n/a	250
	REFU Elektronik	Metzingen	n/a	170
	SMA Solar Technology	Niestetal, Kassel	10.000	4.000
	Solutronic	Großbettlingen	250	30
	Sputnik Engineering	Neuhausen auf den Fildern	1.600	21
	Steca Elektronik	Memmingen	40	510
	Sunways	Konstanz	n/a	145
	Bosch Power Tec	Hamburg	250	100

5 PV IN THE ECONOMY

5.1 Labour places

The long term development in Germany's renewable energy sector is shown in Figure 2. After a peak in the year 2011 (rd. 416.000 employees) the amount of employees has been reduced down to rd. 329.000 in the year 2015. From 2015 to 2016 the total amount of employees slightly increased up to rd. 339.000 (see Table 16).

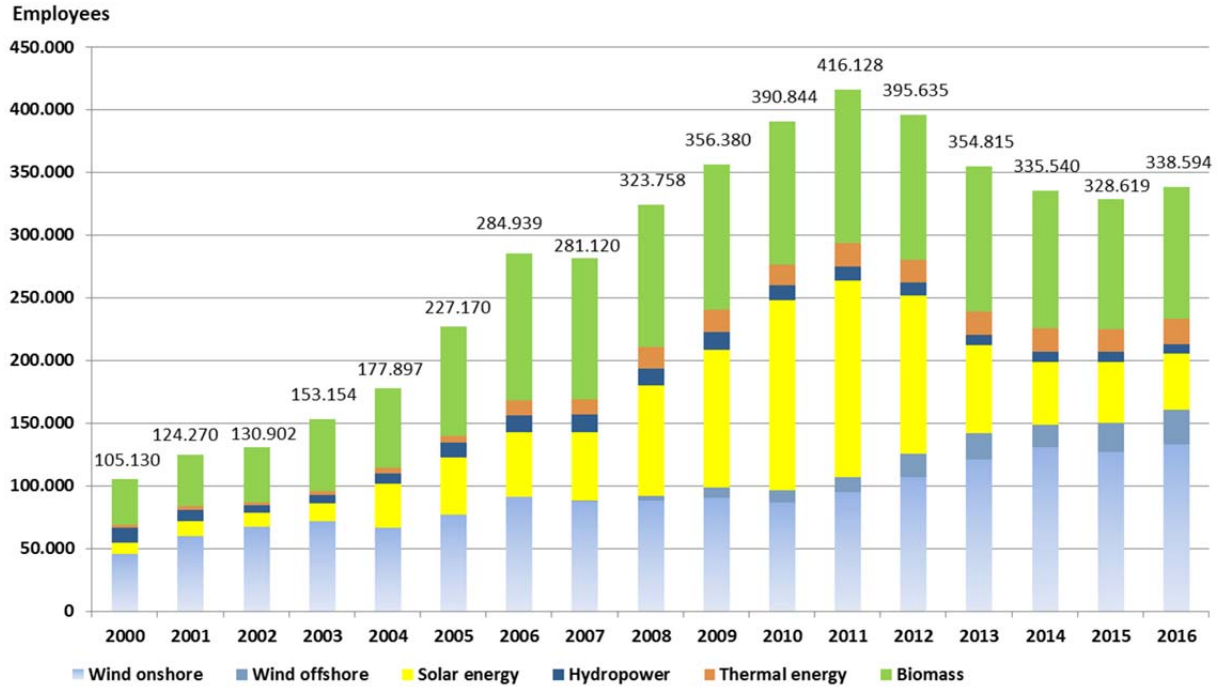


Figure 2: Long term development of gross employment in Germany's renewable energy sector (adapted from [23]).

Table 16 : Development of Germany's gross employment, subdivided in the different categories of renewable energy within the years 2015/2016 (adapted from [23]).

	Employees in 2015	Employees in 2016
Wind Onshore	127.050	132.975
Wind Offshore	22.650	27.124
Solar Energy	48.751	45.261
Hydropower	7.932	7.367
Thermal Energy	18.400	20.300
Biomass	103.837	105.567
In total	**328.619**	**338.594**

5.2 Business value

Table 17: Value of PV business

Sub-market	Capacity installed in 2017 [MW] (from Table 1)	Price per W [EUR] (from Table 5)	Value [MEUR]	Totals [MEUR]
Grid-connected distributed	461 463 375	1,415 1,105 0,975	652,3 511,6 365,6	
Grid-connected centralized	477	0,550	262,4	
				1.792

The Value of the PV business in Germany can be estimated as in Table 17. As there is no reliable data for the value of im- and exports as well as for the stocks, the estimation can only be done with respect to the installed systems and leads to a value of 1,8 Billion EUR. In good accordance, the Federal Ministry of Economic Affairs and Energy published a value of 1,7 Billion EUR for the invest in new PV-Systems during 2017 [3].

6 INTEREST FROM ELECTRICITY STAKEHOLDERS

6.1 Structure of the electricity system

The electricity market and production are affected by five large enterprises:

- EON (Transmission Grid: Tennet TSO GmbH)
- RWE
- Vattenfall
- EnBW
- LEAG

The five market leaders hold 65,3 % of the production capacities and reached a share of 76,5 % regarding the produced electricity.[10] Additionally, there are municipal utilities and independent power producers who generate electricity for their own facilities.
The high voltage transmission grid originally was also controlled by 4 large electricity companies. In order to facilitate a free access, today the transmission grids are operated by independent companies. EnBW has set up a subsidiary which is running the grid. Figure 3 shows the control areas of the four transmission system operators (TSO):

- TenneT TSO GmbH
- Amprion GmbH
- 50Hertz Transmission GmbH
- TransnetBW GmbH

The total transmission grid length summed up to 36.597 km end of 2016 [4].

[10] Electricity production without EEG-electricity. This means in particular, that most renewable electricity sources are not included in the calculation. Due to the availability of data, a part of the EEG-electricity under direct marketing is included.

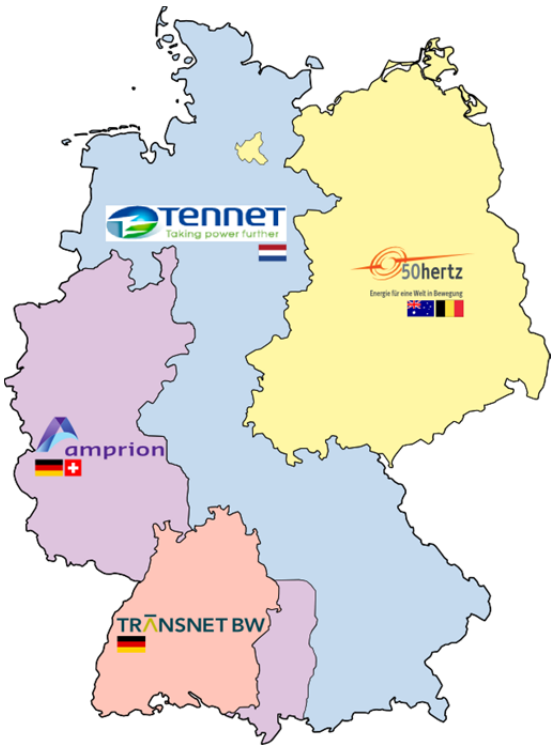


Figure 3: The high voltage transmission grid operators [24].

The final distribution to the customers is carried out by 829 distribution network operators (DNO), controlling a grid length of 1.807.575 km [4].Most of the distribution networks belong to municipal energy suppliers, but some belong to private companies. Figure 4 gives an overview of the expansion of the energy lines.

The projects currently listed in the Federal Requirements Plan Act comprise lines with a total length of some 5,900 km. According to the network development plan, around 3,050 km of these lines will serve to reinforce the system. At the third quarter of 2017, around 450 km had been approved and about 150 km of these completed. A further 2,400 km or so of lines are at the federal sectoral planning stage with the Bundesnetzagentur and around 600 km are at the spatial planning and planning approval stage with the federal state authorities.

The Bundesnetzagentur (Federal Network Agency) is Germany's regulatory authority for the electricity, gas, telecommunications, postal and rail markets. Since 2011, it has also taken on responsibility for implementing the Grid Expansion Acceleration Act (NABEG) [25].

The map in Figure 4 shows the status of the projects listed in the Federal Requirements Plan Act as at the third quarter of 2017 .

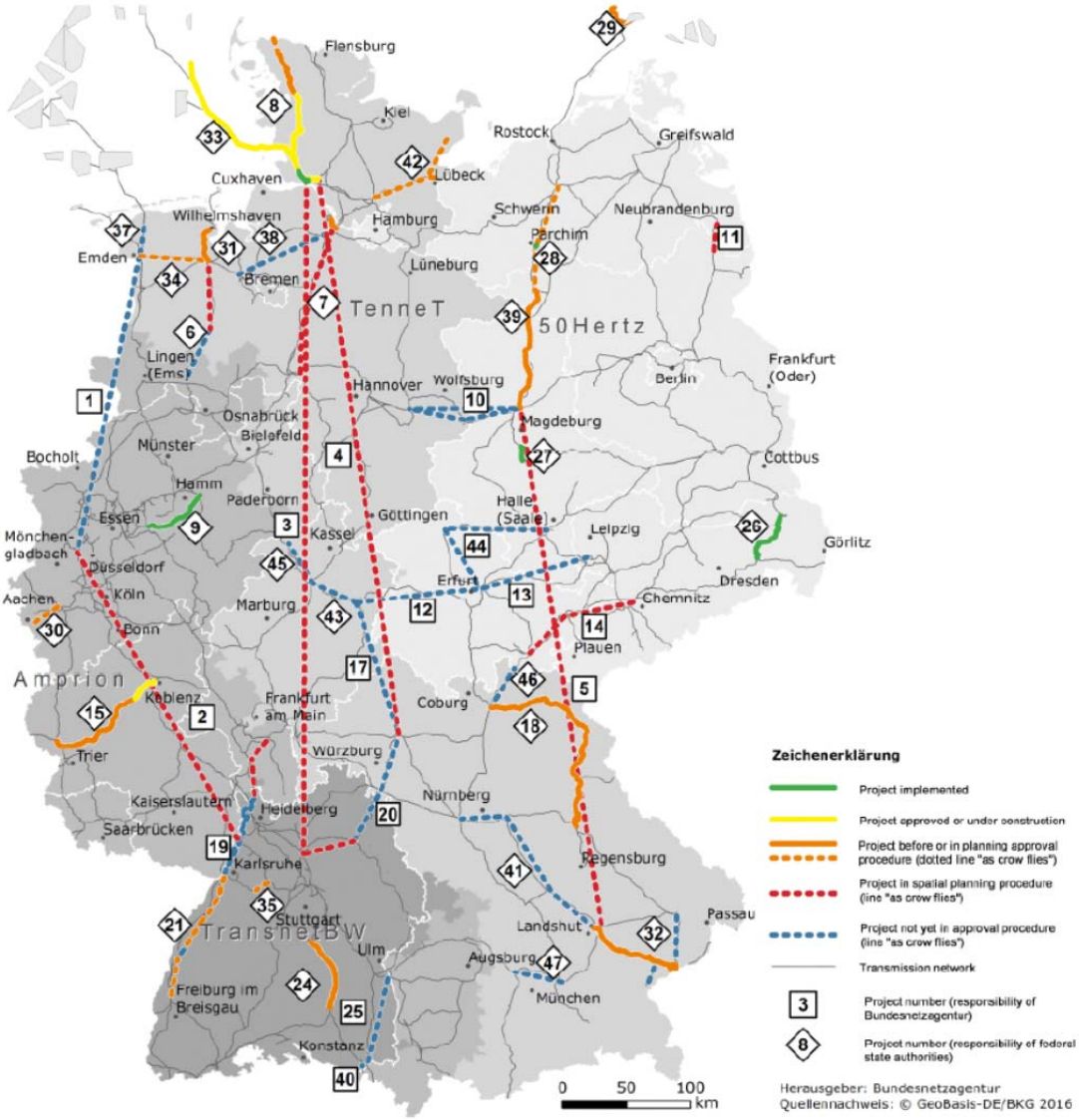


Figure 4: Status of expansion projects in the Federal Requirements Plan Act: 3rd quarter 2017 [26].

6.2 Interest from electricity utility businesses

Driven by the regulatory framework, 4 large enterprises EON, RWE, Vattenfall and EnBW increase their engagement in renewables, the main focus is in the wind sector. EON and RWE started in 2016 to separate their renewable energy part from the conventional power production: RWE transferred the renewables to the newly founded Innogy SE, EON moved the conventional part (including hydropower, but not nuclear) to Uniper SE.

The PV market is dominated by the private sector for roof-top systems and by project developers for ground mounted systems.

Still, due to the large variety of companies in the German energy market, there are numerous concepts from local energy suppliers. Most of the energy suppliers offer green electricity tariffs for their customers and operate their own renewable systems and/or support private PV systems. Among the nationwide acting companies, there are some who only sell electricity from renewables.

7 HIGHLIGHTS AND PROSPECTS

Research and Development (R&D) is conducted under the 6th Programme on Energy Research "Research for an Environmental Friendly, Reliable and Economical Feasible Energy Supply" [27], which came into force in August 2011. Within this framework, the Federal Ministry for Economic Affairs and Energy (BMWi) as well as the BMBF (Federal Ministry of Education and Research) support R&D on different aspects of PV. The main parts of the programme are administrated by the funding agency "Project Management Jülich (PtJ)".

In 2016 the consultation procedure for the 7th Programme on Energy Research started. Experts of economy, research and development, federal and federal state government participate in that process, which will be finished during 2018.

7.1 Highlights of R&D

So far, crystalline silicon solar cells – in particular p-type Passivated Emitter and Rear Contact (PERC) solar cells - are state of the art. However, ongoing research - e. g. concerning passivated selective contacts - still leads to higher levels of efficiency, hence higher yield. Heterojunction solar cells and tandem solar cells are two additional examples for intensive research activities.

One focus of photovoltaic equipment manufactures is the reduction of investment costs for customers ("industry 4.0").

Within the last years cell efficiency of thin film solar cells has been increased. In addition to its cost-efficiency this production technology is suitable for building integrated photovoltaics.

Another approach for cost reduction in photovoltaics is the optimisation of inverters.

More detailed information on ongoing projects can be found in the enArgus database (german language) [28].

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

7.2.1 Funding activities of the Federal Ministry for Economic Affairs and Energy (BMWi)

In December 2014, the BMWi released a new call for tender, which reflects the targets of the 6th energy research program. Concerning PV, the call addresses six focal points which are all connected to applied research:

- Silicon wafer technology,
- Thin-film technologies, especially based on chalcopyrites (CIS/CIGS),
- Quality control and lifetimes
- System technology for both, decentralised grid-connection and island systems,
- Alternative solar cell concepts such as Concentrated PV (CPV)
- Cross-cutting issues like Building Integrated PV (BIPV), recycling or research on the ecological impact of PV systems.

In 2017 the BMWi support for R&D projects on PV amounted to about 81 MEUR shared by 424 projects in total. That year, 103 (2016: 166) new grants were contracted. The funding for these projects amounts to 89,3 (2016: 116,6) MEUR in total. Figure 5 gives a more detailed overview of the funding volume in the years between 2012 and 2017.

Details on running R&D projects can be found in the BMWi publication “Innovation durch Forschung; Erneuerbare Energien und Energieeffizienz: Projekte und Ergebnisse der Forschungsförderung 2017” [29] or via a web-based database of the Federal Ministries [30].
The German contributions to the PVPS tasks 1, 9, 12, 13, 14 and 15 are part of the programme.

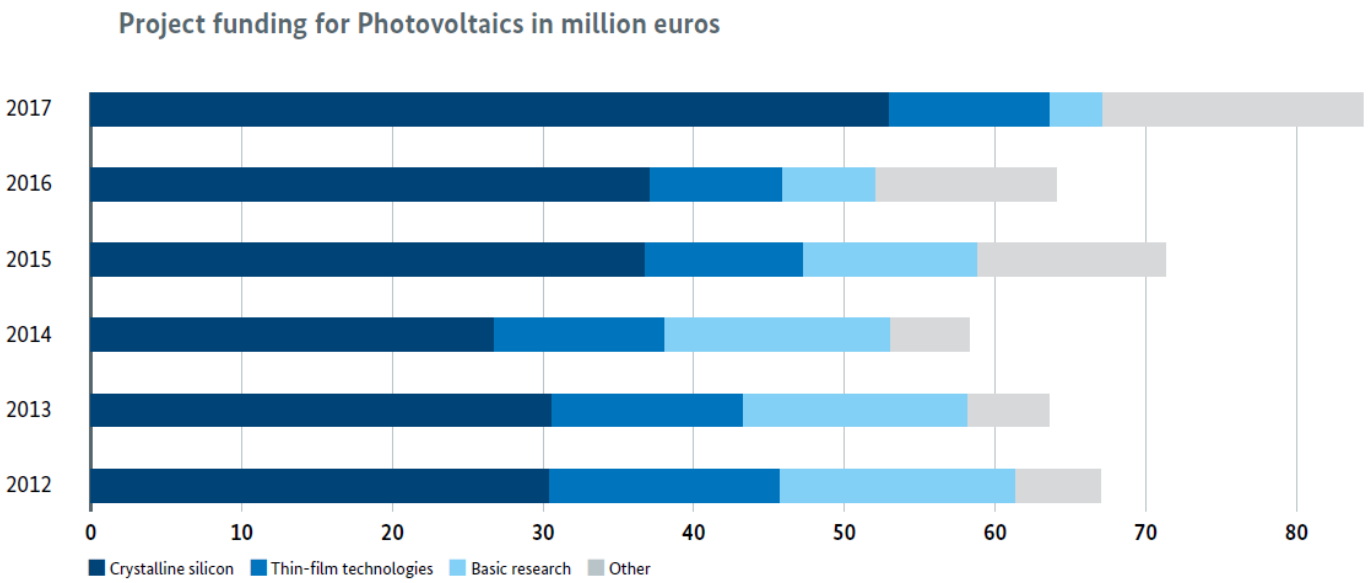


Figure 5: Development of the volume of R&D funding from the Federal Government (adapted from [31]).

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