IEA INTERNATIONAL ENERGY AGENCY

National Survey Report of PV Power Applications in GERMANY 2016

PHOTOVOLTAIC POWER SYSTEMS PROGRAMME

PVPS

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Participation in IEA PVPS activities on behalf of the
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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 2015. 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 system 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 2016 statistics if the PV modules were installed and connected to the grid between 1 January and 31 December 2016, 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 2014 [1]) being the main driving force of the PV market in Germany. It determines the procedure of grid access for renewable energies and guarantees favourable Feed-in-Tariffs (FiT) for them. The FiT depends on size and type (residential, ground mounted, building integrated, …) of the system.

The low FiT for large ground mounted systems led to the fact that during the last years installation numbers decreased in this market sector. 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).

1.2 Development 2016

A capacity of 1.476 MW PV power has been newly installed in Germany in 2016, staying well below the EEG target corridor of 2,4-2,6 GW (see Chapter 3). This results into a total installed PV capacity of 41,3 GW connected to the electricity grid. Subsequently, PV contributed 38,2 TWh (approx. 6,4 %) to the annual gross electricity consumption of 594,7 TWh [2]. The total amount of electricity generated by grid connected PV systems decreased slightly by 1,3 % in comparison to the previous year.

While the monthly installations scattered around 100 MW from January to October, the capacity of newly installed systems increased to 184 MW in November and 441 MW in December. This effect is triggered by the new EEG 2017 coming into force 01.01.2017: From 2017 on, all systems (also BAPV/BIPV) above 750 kWp need to go through tenders to take profit from public EEG funding. Thus, about 71 % (316 MW) of the systems installed in December 2016 were systems above 750 KWp.

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 [3]. 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) [2] 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 2016 [3] [2]

			MW installed in 2016	MW installed in 2016	AC or DC
Grid-connected	BAPV	Residential (<= 10kW)	1225	285[1]	DC
		Commercial (>10 to 250 kW)		302[1]	DC
		Industrial (>250 kW)		695[1]	DC
	BIPV	included in BAPV Data			
	Ground-mounted		251		DC
Off-grid			0		DC
		Total	1.476		DC

Table 2: Data collection process:

Is the collection process done by an official body or a private company/Association?	official body
Link to official statistics (if this exists)	www.bundesnetzagentur.de (German Federal Network Agency [3]) www.erneuerbare-energien.de ("Working Group on Renewable Energy Statistics" AGEE-Stat [2])
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 %.

[1] Values are raw data from [3]. Cumulated, they exceed the total installations by approx. 5 %. Total installations are corrected values from [2], corrections are not available for the partial values.

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

	2016	2015
Total power generation capacities (all technologies)	205,7 GW (31.03.2017) [3]	204,6 GW (31.12.2015) [4]
Total power generation capacities (renewables including hydropower)	104,024 GW [2]	97,9 GW [4]
Total electricity demand (= consumption)	594,7 TWh [2] (preliminary)	594,7 TWh [4]
New power generation capacities installed during the year (all technologies)	6,5 GW [5]	8,3 GW [4][2]
New power generation capacities installed during the year (renewables including hydropower)	6,5 GW [5]	7,6 GW [4]
Total PV electricity production	38,171 TWh [2]	38,726 TWh [2]
Total PV electricity production as a % of total electricity consumption	6,4 % [3]	6,4 % [3]

Table 4: Other information [4]

Number of PV systems in operation in your country (a split per market segment is interesting)	1,56 Mio (2015, preliminary)
Capacity of decommissioned PV systems during the year in MW	N/A
Total capacity connected to the low voltage distribution grid in MW	23,4 GW (2015)
Total capacity connected to the medium voltage distribution grid in MW	13,6 GW (2015)
Total capacity connected to the high voltage transmission grid in MW	2,3 GW (2015)

[2] Main contributions: Renewables (+7,6 GW), Hard coal (+2,5 GW), Nuclear power (-1,2 GW), Natural Gas (-0,5 GW)

[3] Value was calculated based on the actual PV power production in 2016.

Table 5: History of cumulative installations 1990-2016 [2]

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	17,9
2001	0,176	2011	25,4
2002	0,296	2012	33,0
2003	0,435	2013	36,3
2004	1,1	2014	38,2
2005	2,1	2015	39,8
2006	2,9	2016	41,3
2007	4,2		

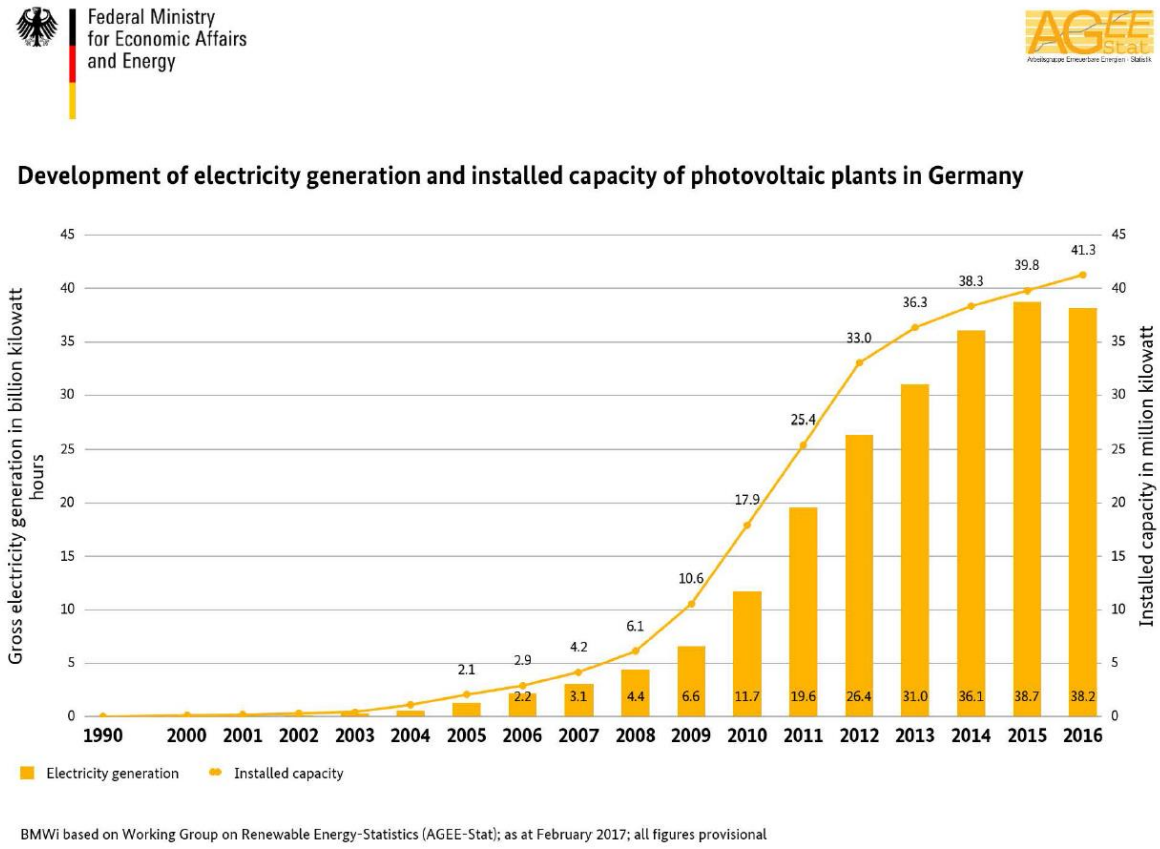

Figure 1: Development of electricity generation and installed capacity [2]

2 COMPETITIVENESS OF PV ELECTRICITY

2.1 Module prices

Table 6 shows the module prices (crystalline silicon) on the European spot market from 2010 to 2016. The prices represent the average prices of December of the corresponding year, averages were determined for different module origins (Germany, China, Japan/Korea, Southeast-Asia/Taiwan) resulting in price ranges (minimum to maximum) between 16 and 31 €cent. End-customer prices for an average turnkey PV system can be estimated a factor 2 to 3 higher [6].

The results of a survey with 100 installers are shown in Table 7. Looking at the different origins of the Modules, it is found that Chinese/Taiwanese modules are sold slightly cheaper in Germany than European/Japanese modules.

Table 6: Typical module prices for a number of years. European spot market prices [€/Wp]. [6]

Year	2010	2011	2012	2013	2014	2015	2016
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

Table 7: Module prices for modules from different origins. 1st quarter 2016. Data collected by a survey with 100 installers. (Net prices without VAT) [7]

Module price [€/Wp]		German	European	Japanese	Chinese/Taiwanese
Silicon monocristalline	min	0,55	0,52	0,49	0,49
	avg	0,63	0,61	0,63	0,60
	max	0,80	0,72	0,90	0,78
Silicon polycristalline	min	0,50	0,53	0,49	0,47
	avg	0,57	0,56	0,60	0,55
	max	0,74	0,69	0,65	0,63

2.2 System prices

Table 8 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. Table 9 displays the development of system prices in the past 10 years.
Investments in PV installations are getting 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. Nevertheless, the price changes during the last 2-3 years are almost negligible: A PV rooftop system in the range of 10 – 100 kW cost about 1 300 EUR/kW (average) in 2016 [8]. The Levelized Costs of Energy (LCOE) for such a PV system are around 0,13 EUR/kWh whereas the average electricity price for a private household is around 0,29 EUR/kWh [9]. Detailed data for 2016 is not yet available.

Table 8: **Turnkey Prices of Typical Applications, 1st quarter 2016 [7]**

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 avg max	1.250 1.688 2.200
Grid-connected Rooftop from 3 to 10 kW	Rooftop systems, mostly for private use, significant share of self-consumption.	min avg max	1.150 1.456 1.750
Grid-connected Rooftop from 10 to 100 kW	Large rooftop systems: agricultural or industrial buildings, predominantly for grid injection	min avg max	950 1.227 1.500
Grid connected ~300 kW		avg	1.084
Grid connected Ground mounted ~1000 kW		avg	1.015
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 0,6 €/Wp	avg	600

Table 9: National trends in system prices (current) for different applications – [€/kWp]

Price/Wp	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Residential PV systems < 10 KW [10]	4.906	4.458	4.359	3.255	2.842	2.147	1.751	1.698	1.640	1.456	N/A
Residential 10 kW-100 kW [11]	N/A	4.313	4.135	3.360	2.708	2.185	1.575	1.378	1.325	1.273	N/A

2.3 Financial Parameters and specific financing programs

2.3.1 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 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 10: Country information

Retail Electricity Prices for an household (range) (2015) [€ct/kWh] [9]	29,11
Retail Electricity Prices for a commercial company (range) [€ct/kWh] [9]	13,45 - 16,48 avg 14,20
Retail Electricity Prices for an industrial company (range) (2015) [€ct/kWh] [9]	4,32
Population (31.12.2015) [12]	82.175.700
Country size [km^2]	357.375
Global solar irradiation (2016) [kWh/m^2] [13]	min 947 avg 1.079 max 1.359
Average PV yield (according to the current PV development in the country) [kWh/kWp]	942 (average 2016) 1.050 (expected average under best operation conditions)
Name and market share of major electric utilities (2015) [4]	RWE (32,2 %) Vattenfall (21,4 %) EnBW (12,6 %) E.ON (9,9 %)

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, 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 [14]. Moreover, it was decided in 2011 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). [15]
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 2015, 14,8 % were reached [2]). 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. 31,7 % (2015: 31,5 %) [2] of the gross electricity consumption of Germany in 2016. This is already close to the first target for 2020 of the Energy Concept.

Photovoltaic reached a share of 6,4 % of gross electricity consumption and thus is a major part of this development driven by the Renewable Energy Sources Act (EEG 2014 [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

3.1.1 New, existing or phased out measures in 2016

3.1.1.1 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 2016 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 (see Table 12). From 2017 on, the monthly degression rates will be slightly changed if installations in the last months are below a yearly average of 2,6 GW.

- Market integration model: This model can be used for systems on residential or non-residential (lower FiT) buildings up to 10 MWp. 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 > 10 MWp) there were three calls for tenders: see Chapter 3.3

This procedure of "breathing rates" tends to stimulate a yearly installation of 2,4 – 2,6 GW. No further reductions of the FiT was executed from October 2015 on and throughout 2016 since the installed capacity dropped well below this range in the corresponding assessment period (see Table 12).

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 11: Overview: Feed in Tariffs for different system types [3]

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 2016 [€ct]	12,31	11,97	10,71	8,53

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 - 1.000	< 10.000
FiT 2016 [€ct]	12,70	12,36	11,09	8,91

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

Table 12: Monthly degression of the feed-in Tariff. From 2017 on, the degression rates are slightly changed in order to better support the politically defined goals.

Installations in the last 12 months [GWp]	Monthly change of FiT (2014- 2016) [%]	Monthly change of FiT (changes valid from 2017 on) [%]
> 7,5	-2,8	-2,8
6,5 - 7,5	-2,5	-2,5
5,5 - 6,5	-2,2	-2,2
4,5 - 5,5	-1,8	-1,8
3,5 - 4,5	-1,4	-1,4
2,6 - 3,5	-1,0	-1,0
2,5 - 2,6	-0,5	-1,0
2,4 - 2,5	-0,5	-0,5
2,3 - 2,4	-0,25	-0,5
2,1 - 2,3	-0,25	-0,25
1,7 - 2,1	-0,25	0
1,5 - 1,7	-0,25	+1,5 (per quarter)
1,3 - 1,5	0	+1,5 (per quarter)
1,0 - 1,3	0	+3,0 (per quarter)
< 1	+1,5 (per quarter)	+3,0 (per quarter)

3.1.1.2 BIPV development measures

There were no special measures favouring the development of PV as building element in Germany in 2016.

3.1.1.3 Support for electricity storage and demand response measures

Since 2013 the KfW (see also Chapter 2.3.1) 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 2016, the installation of a storage system was funded for 6.468 storage systems (800 for existing and 5.668 for newly installed PV systems), with the total volume of loans reaching 105 MEUR.

During the first phase (2013-2015), more than 17.000 storage systems were funded. [16] [17]

Table 13: 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 14 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 14: Self-consumption measures

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 3.1.1)
	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 2016 covered a capacity of around 400 MW altogether and were characterized by a high degree of competition.
As shown in Table 15, the proposed capacity was in all calls significantly over-subscribed and the price level was reduced from call to call.

Table 15: Calls for ground-mounted systems (overview 2015-2016) [3]

Call Deadline	Apr 15	Aug 15	Dec 15	Apr 16	Aug 16	Dec 16
	Pay-as-bid	Uniform pricing	Uniform pricing	Pay-as-bid	Pay-as-bid	Pay-as-bid
Volume [MW]	150	150	200	125	125	160
Bids	170	136	127	108	62	76
Total volume of bids [MW]	715	558	562	539	311	423
Accepted bids	25	33	43	21	22	27
Accepted volume [MW]	157	159	204	128	118	163
Average price [€ct/kWh]	9,17	8,49	8,00	7,41	7,25	6,90
Commissioning deadline	May 17	Aug 17	Dec 17	Apr 18	Aug 18	Dec 18

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 2015 the EEG-levy amounted to 6,35 €ct/kWh (2015: 6,17 €ct/kWh, 2017: 6,88 €ct/kWh). There are special treatments for energy intensive industries. [1]

4 HIGHLIGHTS OF R&D

4.1 Highlights of R&D

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" [18], 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)".

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 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.

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 should be finished in 2018.

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

4.2.1 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 2016 the BMWi support for R&D projects on PV amounted to about 57,8 MEUR shared by 366 projects in total. That year, 166 (2015: 97) new grants were contracted. The funding for these projects amounts to 116,6 (2015: 78,6) MEUR in total. **Figure 2** gives a more detailed overview of the funding volume in the years between 2012 and 2016.
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 2016" [19] or via a web-based database of the Federal Ministries. [20].
The German contributions to the PVPS Tasks 1, 12, 13 and 14 are part of the programme.

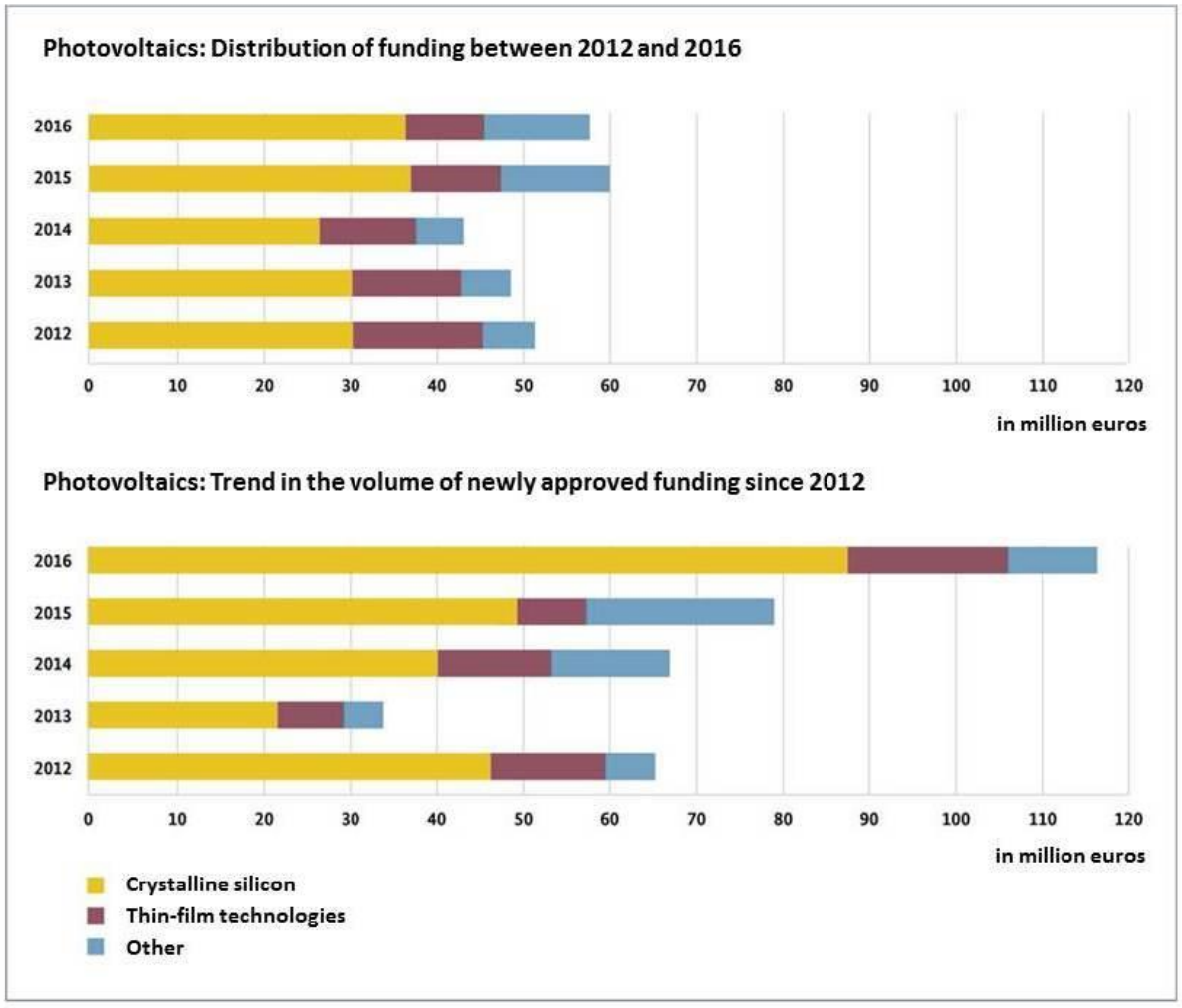

Figure 2: Development of the volume of R&D funding from the Federal Ministry for Economic Affairs and Energy (BMWi) (adapted from [19]**).**

4.2.2 Funding Activities of the Federal Ministry of Education and Research (BMBF)

From 2013 to 2015, the BMBF funded PV projects under the program "Material Research for the Energy Transition" aiming for the support of long-term R&D which is complementary to the BMWi funding. From September 2015 on, the BMBF relaunched its energy related funding under the "Kopernikus" initiative. Under this scheme cooperative research on four central topics of the "Energiewende" will be addressed: storage of excess renewable energy, development of flexible grids, adaption of industrial processes to fluctuating energy supply and the interaction of conventional and renewable energies.

4.2.3 "R&D for Photovoltaics" – a Joint Initiative of BMWi and BMBF

To support the momentum stimulated by the "Innovation Alliance PV" of 2010, a new joint initiative of BMWi and BMBF has been launched in 2013. The aim of this 3 year programme "R&D for Photovoltaics" is to support R&D activities especially with participation of the German PV industry in the fields of

- economical operation of grid-connected and off-grid PV system solutions including energy management and storage systems
- efficient and cost effective production concepts including the introduction of new materials and production monitoring systems
- introduction of new PV module concepts with a special focus on quality, reliability and life time

The running 13 joint projects are funded by the ministries BMWi and BMBF with a total budget of about 50 MEUR.
A mid-term evaluation took place in early 2016. First results show a 22 % record cell efficiency for a p-type PERC solar cell using industrial standard materials and processes only. [21]

5 INDUSTRY

5.1 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 16 [22], [23]. 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 [24]. Remark: Solarworld AG announced their insolvency in May 2017.

Table 16: Production information for silicon feedstock in 2016 [22], [23], [24] .

Manufacturers (or total national production)	Process & technology	Total production [t]
Schmidt Polysilicon Production GmbH	Silicon feedstock	180
Silicon Products Group	Silicon feedstock	1.800
Wacker Chemie AG	Silicon feedstock	66.000

5.2 Production of photovoltaic cells and modules (including TF[4] and CPV[5])

Table 17 and Table 18 give an overview of the solar cell and module manufacturers with production capacity and number of employees [22].

Table 17: Production and production capacity information of solar cell manufacturer in 2016 [22]

Cell manufacturer	Location	Production capacity [MWp]	Employees
aleo sunrise GmbH	Prenzlau	100	n/a
Bluecell GmbH[6]	Arnstadt	100	84
Solar World AG[7]	Arnstadt	700	> 250
Solar World AG[7]	Freiberg	330	> 250

[4] Thin Film: CIGS, CdTe, OPV

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

[6] Insolvency 06/2017

[7] Insolvency 05/2017

Table 18: Production and production capacity information of module manufacturer in 2016 [22]

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[7]	Arnstadt	Si	200	> 250
Solarworld AG[7]	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

5.3 Manufacturers and suppliers of other components

Balance of system component manufacture and supply is an important part of the PV system value chain. Table 19 shows German manufacturers of such components.

Table 19: Overview of balance of system component manufacturers [22]

	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
Cables	bedea	Aßlar, Herborn		320
	Draka Cable Wuppertal	Wuppertal		500
	HELUKABEL	Windsbach		450
	HEW-KABEL	Wipperfürth		320
	HI Kabelkonfektionierung	Beerfelden		120
	HUBER+SUHNER	Taufkirchen		140
	KBE Elektrotechnik	Berlin		220
	Klasing Kabel	Denkendorf		170
	KWV Kabelwerke	Villingen-Schwenningen		30
	Lumberg Connect	Schalksmühle, Cloppenburg		1000
	Multi-Contact	Weil am Rhein		120
	Nexans	Hannover		400
	PRYSMIAN	Eschweiler, Schwerin		110
	Sykonec	Neustadt bei Coburg		42

	Company	Location	Capacity 2012 [MWp]	Employees at respective location
	Tyco Electronics	Bensheim		1.950
	U.I. Lapp	Stuttgart		800
	VOKA	Plauen, Falkenstein		500
	XBK-Kabel	Rottweil		200
	Yamaichi Electronics	Frankfurt (Oder)		150
Connectors	Amphenol-Tuchel	Heilbronn		300
	Büschel	Jungingen		30
	Citel	Bochum		130
	HI Kabelkonfektionierung	Beerfelden		120
	Hirschmann	Neckartenzlingen, Ettlingen, Schalksmühle		350
	Huber + Suhner	Taufkirchen		200
	Huonker	Villingen-Schwenningen		100
	Lumberg Connect	Schalksmühle, Cloppenburg		800
	Molex	Bretten		80
	Multi-Contact	Weil am Rhein		120
	Pöppelmann Kunststoff-Technik	Lohne		350
	U.I.Lapp GmbH	Stuttgart		800
	Wieland Electric	Bamberg		1.000
	Yamaichi Electronics	Frankfurt (Oder)		150
Tracking systems own manufacturing	a+f	Würzburg		109
	DEGERenergie	Horb		30
	Eggert	Oberstadion		25
	EGIS-Equipment	Offenbach		5
	EQ-SYS	Treuenbrietzen		21
	Galaxy Energy	Heroldstatt		35
	Green Factory	Heidenheim		10
	GSM Solar	Mamming		90
	Hanse Solar	Wismar		12
	IMO Anlagenbau	Gremsdorf		50
	Kemper	Vreden		100
	Bernt Lorentz	Henstedt-Ulzburg		25
	Löseke & Marx Maschinenbau	Paderborn		30
	mp-tec	Eberswalde		70
	PV-Eiwa	Plattling		100
	PVStrom Energy Systems	Kirchheim am Neckar		25
	Schüco International	Bielefeld		1.500
	Altec Solartechnik	Sömmerda		70

	Company	Location	Capacity 2012 [MWp]	Employees at respective location
	Solarpark Rödenäs	Rodenäs		50
	Solea	Platting		29
	sonnen_systeme	Alheim-Heinebach		100
Tracking systems - OEM production in Germany	Energiebau Solarstromsysteme	Köln		300
	IDEEMATEC	Wallerfing		16
	RWenergy	Schwandorf		30
	S+S Energietechnik	Lüchow-Grabow		5
	Solar-Track	Lübeck		10
	Bosch Power Tec	Hamburg		100
Mounting systems - own manufacturing	ALTEC Solartechnik	Crispendorf, Sömmerda		185
	Benz Alusysteme	Ingersheim		15
	CEKO	Neresheim		15
	EQ-SYS	Treuenbrietzen		20
	Fath Solar	Spalt		100
	Grammer Solar	Amberg		50
	Metall Josten	Düsseldorf		25
	Mounting Systems (Conergy)	Rangsdorf		250
	mp-tec	Eberswalde		70
	MÜPRO	Hofheim-Wallau		n/a
	Niemetz Metall	Königsfeld		50
	PV-Eiwa	Plattling		100
	RegTec	Augsburg, Wiesthal, Bad Berka		20
	Schletter	Kirchdorf		400
	Solarpark Rodenäs	Rodenäs		50
	Solarstep	Königstein		6
	Soltech	Bielefeld		15
	TS-Aluminium	Großefehn, Burgsstädt		85
	VM Edelstahltechnik	Plettenberg		20
	Wagener & Simon	Wuppertal		180
	Wagner & Co. Solartechnik	Cölbe		400
	Wilhelm Flender	Netphen		75
	Zambelli	Grafenau		650
	Zentralsolar	Rheine		25
	Zinco	Unterensingen		70

	Company	Location	Capacity 2012 [MWp]	Employees at respective location
Mounting systems - OEM production in Germany	alfasolar	Hannover		40
	E.u.r.o Tec	Hagen		30
	ECOSOLAR	Duisburg		9
	Energiebau Solarstromsysteme	Köln		300
	HABDANK PV-Montagesysteme	Göppingen		40
	HELTRON	Breisach		19
	IDEEMATEC	Wallerfing		16
	K2 Systems	Weil der Stadt		45
	PanelClaw	Wuppertal		23
	Renusol	Köln		90
	RWenergy	Schwandorf		30

6 PV IN THE ECONOMY

6.1 Labour places

From 2014 to 2015 the total amount of employees in the field of renewable energy decreased from 355.400 to 330.000 (seeTable 20). Only in the sectors “wind offshore”, “deep thermal energy” and “biomass (small plants)” the number of employees could be slightly increased. The most significant reduction is observed for the sector of “wind onshore”.

The long term development in Germany’s renewable energy sector is shown in Figure 3. After a peak in the year 2012 (399.800 employees) the amount of employees has been reduced down to 355.400 in the year 2014. However, this is still more than doubling compared to 2004. Most affected by external circumstances (e. g. market development) is the sector of “solar energy”.

Table 20 : Development of Germany’s gross employment, subdivided in the different categories of renewable energy within the years 2014/2015 (adapted from [25]).

	Employees in 2014	Employees in 2015
Wind Onshore	130.500	122.400
Wind Offshore	18.700	20.500
Photovoltaics	38.300	31.600
Solar thermal	10.300	9.900
Solar thermal power plants	700	700
Hydropower	11.800	6.700
Deep thermal energy	1.100	1.200
Near surface thermal energy	16.100	16.100
Biogas	48.300	45.000
Biomass (small plants)	25.400	26.500
Biomass combined heat and power plant	23.100	18.900
Biofuel	23.100	22.800
Publicly funded research / administration	8.000	7.700
In total	**355.400**	**330.000**

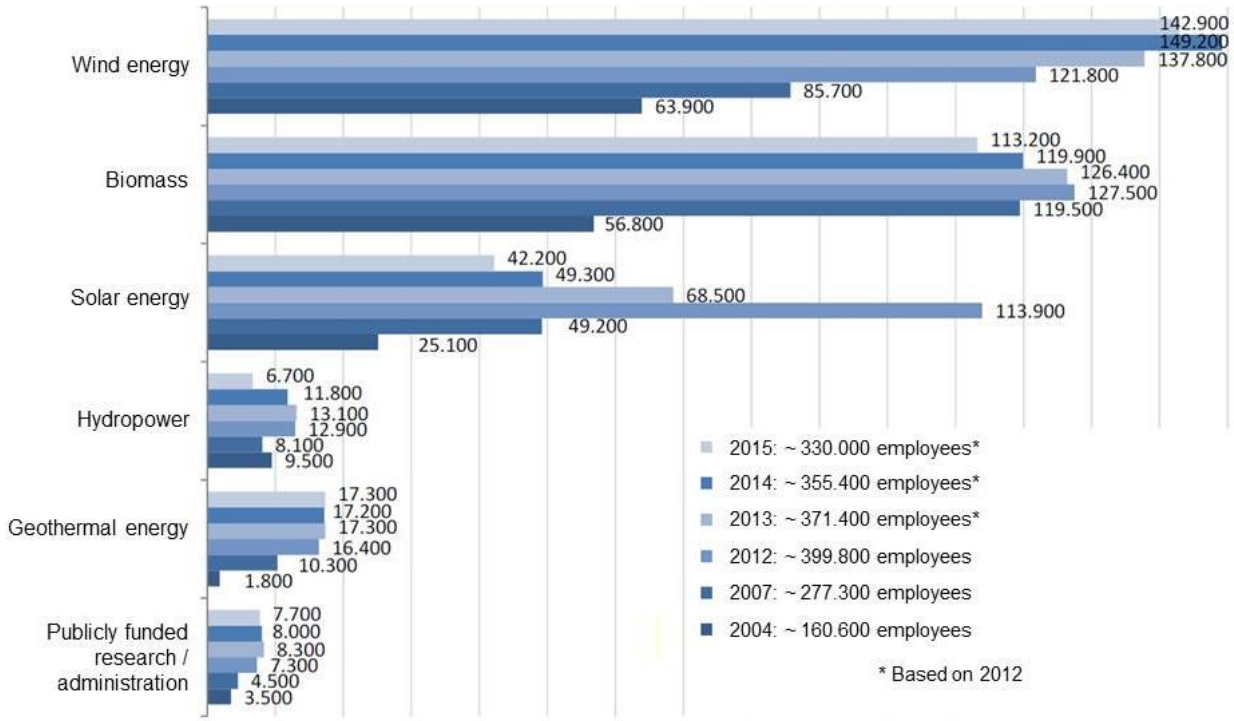

Figure 3: Long term development of gross employment in Germany's renewable energy sector (adapted from [25]). Data for 2016 is not available.

6.2 Business value

Table 21: Value of PV business

Sub-market	**Capacity installed in 2016 [MW]** (from Table 1)	**Price per W [EUR]** (from Table 8)	**Value [MEUR]**	**Totals [MEUR]**
Grid-connected distributed	285 302 695	1,500 1,227 1,084	427,5 370,6 753,4	
Grid-connected centralized	251	0,600	150,6	
				1.702
Export of PV products				N/A
Change in stocks held				N/A
Import of PV products				N/A

The Value of the PV business in Germany can be estimated as in Table 21. 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 1,7 Billion EUR. In good accordance, the Federal Ministry of Economic Affairs and Energy published a value of 1,6 Billion EUR for the invest in new PV-Systems during 2016 [2].

7 INTEREST FROM ELECTRICITY STAKEHOLDERS

7.1 Structure of the electricity system

The electricity market and production are affected by 4 large enterprises:

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

The four market leaders hold 67,6 % of the production capacities and reached a share of 76,2 % regarding the produced electricity.[8] 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 the 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 4 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 36.001 km in 2015 [26].

Figure 4: The high voltage transmission grid operators [27].

The final distribution to the customers is carried out by 817 distribution network operators (DNO), controlling a grid length of 1.780.856 km [26]. Most of the distribution networks belong to municipal energy suppliers, but some belong to private companies. Figure 5 gives an overview of the expansion of the energy lines.

[8] 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.

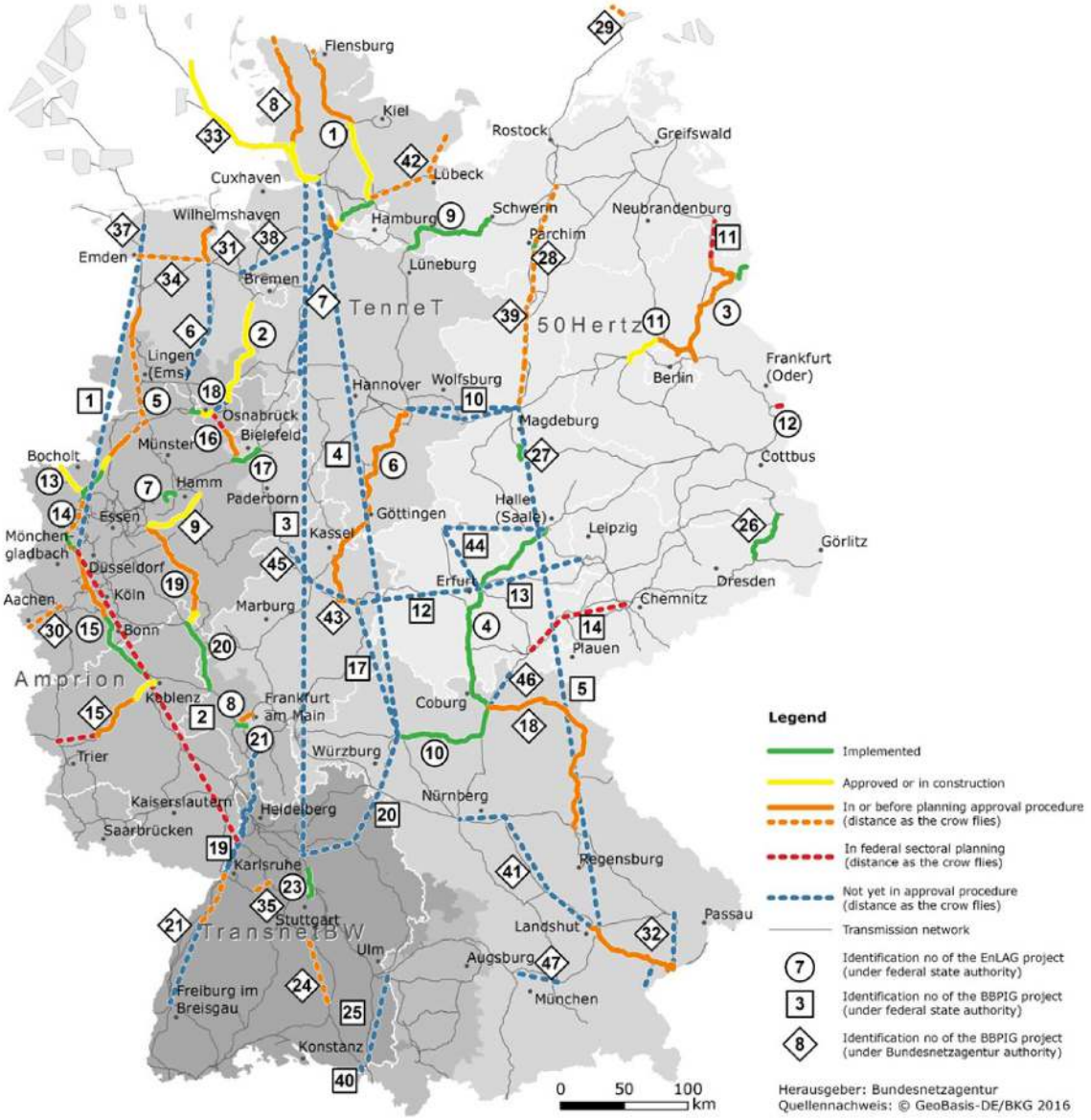

Figure 5: Status of the expansion of energy lines pursuant to the Energy Line Extension Act (EnLAG) and the Gesetz über den Bundesbedarfsplan (BBPlG) in the fourth quarter of 2016 [28].

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) [22] [29].

7.2 Interest from electricity utility businesses

Driven by the regulatory framework, the 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.

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