Renewable energy in Germany

Germany has been called "the world's first major renewable energy economy".[1][2]

On Sunday 15 May 2016 at 14:00 hours, renewables supplied nearly all of domestic electricity demand.[3]

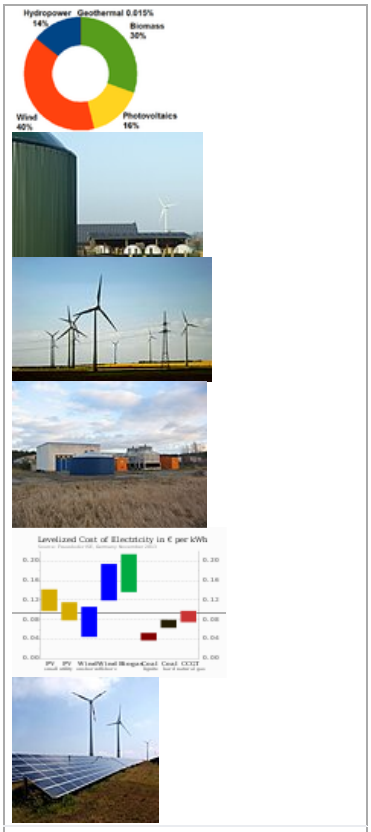
While peak-generation from combined wind and solar reached a previous all-time high of 74% in April 2014,[4] wind power saw its best day ever on December 12, 2014, generating 562 GWh.[5]

More than 23,000 wind turbines and 1.4 million solar PV systems are distributed all over the country's area of 357,000 square kilometers.[6][7] As of 2011, Germany's federal government is working on a new plan for increasing renewable energy commercialization,[8] with a particular focus on offshore wind farms.[9] A major challenge is the development of sufficient network capacities for transmitting the power generated in the North Sea to the large industrial consumers in southern parts of the country.[10]

According to official figures, some 370,000 people were employed in the renewable energy sector in 2010, especially in small and medium-sized companies.[11] This is an increase of around 8% compared to 2009 (around 339,500 jobs), and well over twice the number of jobs in 2004 (160,500). About two-thirds of these jobs are attributed to the Renewable Energy Sources Act.[12][13]

Germany's energy transition, the *Energiewende*, designates a significant change in energy policy from 2011. The term encompasses a reorientation of policy from demand to supply and a shift from centralized to distributed generation (for example, producing heat and power in very small cogeneration units), which should replace overproduction and avoidable energy consumption with energy-saving measures and increased efficiency.

According to a 2017 survey conducted for the German Renewable Energies Agency **Cite error: The `<ref>` tag has too many names (see the help page).** among 1016 respondents, 95 percent of the Germans support further expanding renewable energy. Almost two-thirds of the interviewees agree to renewable power plants close to their homes. The support increases further if respondents already had experience with such plants in their neighborhood. With solar farms it increases from 72 to 94%, with wind power from 57 to 69% and with biogas from 39 to 56%.



Renewable Energy in Germany *(from top left to bottom right)*:
・Renewables in the German electricity sector
・Biogas fermenter in Hornstet
・Wind park in Bernburg
・Geothermal power plant in Neustadt-Glewe
・German Levelized cost of electricity in 2013
・German wind and solar in Rhineland-Palatinate

Targets

Since the passage of the Directive on Electricity Production from Renewable Energy Sources in 1997, Germany and the other states of the European Union were working towards a target of 12% renewable electricity by 2010. Germany passed this target early in 2007, when the renewable energy share in electricity consumption in Germany reached 14%.[16] In September 2010, the German government announced ambitious energy targets:[17]:5 After the 2013 elections, the new CDU/CSU and SPD coalition government continued the energy transition, with only minor modifications of its targets in the coalition agreement.[18] These targets include, for renewable energy:

Renewable energy targets (with actual figures for 2015)[19]

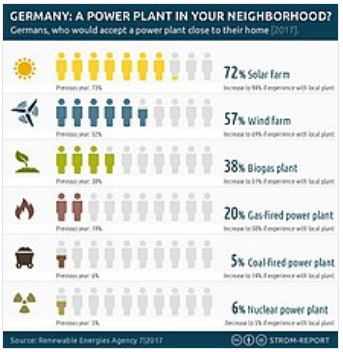
Target	2015	2020	2030	2040	2050
Share of gross final energy consumption	14.9%	18%	30%	45%	60%
Share of gross electricity consumption	31.6%	≥35%	≥50%	≥65%	≥80%
Share of heat consumption	13.2%	14%	N/A	N/A	N/A
Share in transport sector	5.2%	10%	N/A	N/A	N/A

The German Government reported, in 2011, renewable energy (mainly wind turbines and biomass plants) generated more than 123 TWh of electricity, providing nearly 20% of the 603 TWh of electricity supplied.[20]

In 2012, all renewable energy accounted for 21.9% of electricity, with wind turbines and photovoltaic providing 11.9% of the total.[21]

Chancellor Angela Merkel, along with a vast majority of her compatriots, believes, "As the first big industrialized nation, we can achieve such a transformation toward efficient and renewable energies, with all the opportunities that brings for exports, developing new technologies and jobs".[22]

As of 2016, renewable sources account for 33.9% of the net electricity production. Compared to the same period of 2015, energy production from renewable energy sources remained on the same level, while it increased for gas by 15.1 TWh and decreased for the remaining fossil fuels by 16.6 TWh. The increase in energy production from gas can be traced back to low gas prices.[15]:4,5



Survey of public opinion: Germans, who would accept a power plant close to their home.[14]

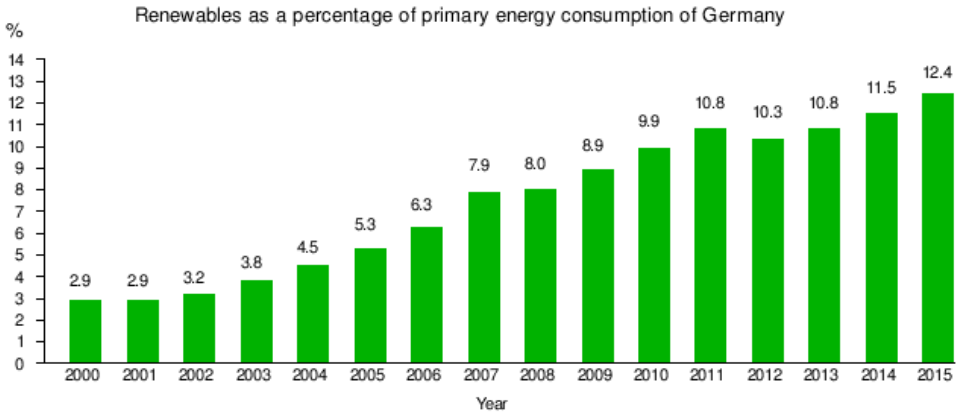
Primary energy consumption

As of 2015 Germany's primary energy consumption of 13 218 petajoules or 3 672 terawatt-hours refers to the total energy used by the nation. The final renewable energy consumption, split by the sectors, and with their relative share, are:[23]:4,5,10

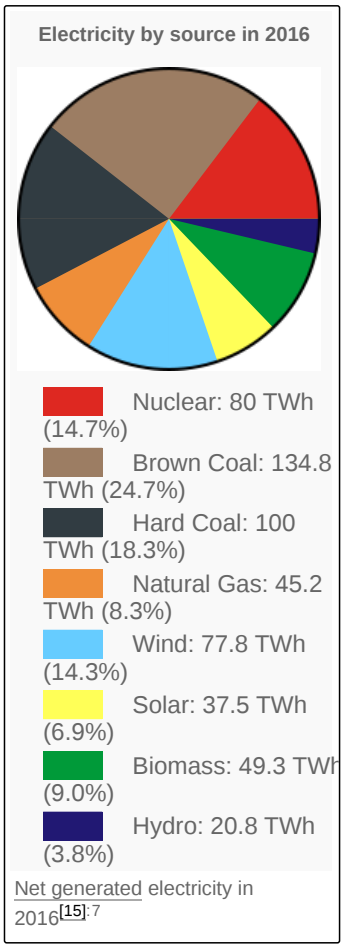
- *Electricity* sector, with a renewable energy consumption of 31.5% (187.364 GWh)
- *Heating* sector, with a renewable energy consumption of 13.3% (158.662 GWh)
- *Transportation* sector, with a renewable energy consumption of 5.3% (33.611 GWh)

As of the end of 2015, renewable energy sources, such as biomass, biogas, biofuels, hydro, wind and solar, accounted for 12.4% of the country's primary energy consumption, a more than doubling compared to 2004, when renewables only contributed 4.5%.[23]:5

Although the terms "energy" and "electricity" are often used interchangeably, they should not be confused with one another, as electricity is only one form of energy and does not account for the energy consumed by combustion engines and heat boilers, used in transportation by vehicles and for the heating of buildings.



Source: *Federal Ministry for Economic Affairs and Energy, 2000–2015*, as per February 2016[23]:5



Net generated electricity in 2016[15]:7

Sources

A travel guide to renewable energy destinations in Germany was published in 2016.[24]

Wind power

In 2013, wind power generated a total of 53.4 TWh of electricity and more than 3.2 GW of new capacity was added to the grid.[26] In 2011, the country's installed capacity of wind power reached 29,075 megawatts (MW), about 8% of the overall capacity.[27] According to EWEA, in a normal wind year, installed wind capacity in Germany will meet 10.6% at end 2011 and 9.3% at end 2010 of the German electricity needs.[28][29]

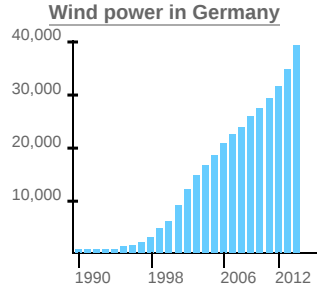
More than 21,607 wind turbines are located in the German federal area and the country has plans to build more.[30][31] As of 2011, Germany's federal government is working on a new plan for increasing renewable energy commercialization,[8] with a particular focus on offshore wind farms.[9] A major challenge is the development of sufficient network capacities for transmitting the power generated in the North Sea to the large industrial consumers in southern Germany.[10] In 2016, Germany decided to replace feed-in tariffs with auctions from 2017.[32]

Biomass

The key provider of biomass supply in Germany is supposed to be agriculture. Moreover, 40% of German wood production is also used as a biomass feedstock.[33] The German Federal Research Centre for Forestry and Forest Products claims that there are also reserves which may assist in enlarging the part of forestry in biomass production. Agriculture is the main source of rapeseed oil, which is used for the production of biodiesel and making substrates for the production of biogas.[34]

Biomass used for the production of biogas and biofuels are some of Germany's most important sources of renewable energy. In 2010, biomass accounted for 30% of renewable electricity generation and for 70% of all renewable energy (mostly wood).[35]

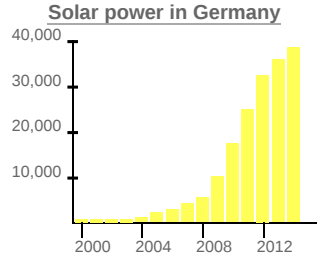
Germany has committed to blending 6.25% biofuels in petroleum by 2014 with the Biofuels Quota Act.[36][37]



Wind power: installed capacity in MW (1990–2014)[25]

Photovoltaic solar power

Solar photovoltaic (PV) technology generates electricity from sunlight, and it can be used in grid-connected and off-grid applications. They were first mass-produced in the year 2000, when German environmentalists and Eurosolar have succeeded in obtaining the government support for the 100,000 roofs program.[39] In July 2012, a cumulative installed total solar PV power of 29.7 GW was in place.[40] Solar PV provided 18 TW·h in 2011, 3% of the total electricity demand. As solar power installations rise quickly, in first half of 2012, about 5.3% of the total electricity demand was covered by solar power.[41] On Saturday May 25, 2012, solar power broke a new record high, feeding 22 GW into the power grid, or as much as 20 nuclear power stations. This jump above the 20 GW level was due to increased capacity and excellent weather conditions countrywide, and made up for half of the nation's electricity demand at midday.[42] Germany was also the biggest expanding market for solar PV 2012, with 7.6 GW of newly connected systems.[43] Some market analysts expect the solar electricity share could reach 25% by 2050.[44] Price of PV systems has decreased more than 50% in 5 years since 2006.[45]



Solar power: installed capacity in MW (2000–2014)[38]

Hydroelectricity

The total installed hydroelectic capacity in Germany at the end of 2006 was 4.7 GW. Hydropower meets 3.5% of the electricity demand. Latest estimates show, in Germany in 2007, about 9,400 people were employed in the hydropower sector which generated a total turnover of €1.23 billion.[46]

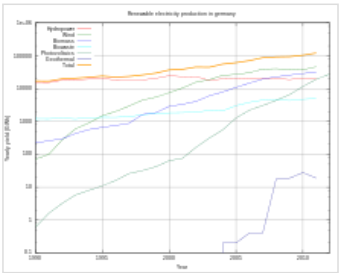
Geothermal power

Geothermal power in Germany is expected to grow, mainly because of a law that benefits the production of geothermal electricity and guarantees a feed-in tariff. But after a renewable energy law that introduced a tariff scheme of €0.15 [US$0.23] per kilowatt-hour (kWh) for electricity produced from geothermal sources came into effect that year, a construction boom was sparked and the new power plants are now starting to come online.

Industry

Germany's renewable energy sector is among the most innovative and successful worldwide. Enercon, Nordex, REpower Systems, Siemens, and Fuhrländer are wind-power companies based in Germany. SolarWorld, Q-Cells, and Conergy are solar-power companies based in Germany. These companies dominate the world market. Every third solar panel and every second wind rotor in Germany are German, and German turbines and generators used in hydro energy generation are among the most popular worldwide.[47]

Nearly 800,000 people work in the German environment technology sector; an estimated 214,000 people work with renewables in Germany, up from 157,000 in 2004, an increase of 36%.[47]


Annual yield of domestic renewable electricity by source.

Siemens chief executive Peter Löscher believes Germany's target of generating 35% of its energy from renewables by 2020 is achievable – and, most probably, profitable for Europe's largest engineering company. Its "environmental solutions" portfolio, which is firmly focused on renewables, is "already generating more than €27 billion a year, 35 per cent of Siemens' total revenue, and the plan is to grow this to €40 billion by 2015". Ending its involvement in nuclear industry will boost the credibility of Siemens as a purveyor of "green technology".[48]

Germany's main competitors in solar electricity are Japan, the US, and China. In the wind industry, it is Denmark, Spain, and the US.

Government policy

The renewable energy sector benefited when the Alliance '90/The Greens party joined the federal government between 1998 and 2005. Support for renewable energy continued under all following governments, regardless of composition, including the current CDU/CSU and SPD coalition government starting in 2013.[18] The renewable energy sector was aided especially by the Renewable Energy Sources Act that promotes renewable energy mainly by stipulating feed-in tariffs and recently also market premiums that grid operators must pay for renewable energy fed into the power grid. People who produce renewable energy can sell their 'product' at fixed prices for a period of 20 or 15 years. This has created a surge in the production of renewable energy.[49] In 2012, Siemens estimated the total cost of renewable energy would come to at least €1.4 trillion (US$1.8 trillion) by 2030.[50]

For the 2011–2014 period, the federal government set aside 3.5 billion euros for scientific research in the country.[51] Additionally, in 2001 a law was passed requiring the closing of all nuclear power plants within a period of 32 years. The shutdown time was extended to 2040 by a new government in 2010. After the Fukushima incident, the law was abrogated and the end of nuclear energy was set to 2022.[52] After the 2013 federal elections, the new CDU/CSU and SPD coalition in important areas continued the *Energiewende* of the previous government, but also agreed on a major revision of the EEG.[53]

The German energy policy is framed within the European Union, and the March 2007 European Council in Brussels approved a mandatory energy plan that requires a 20% reduction of carbon dioxide emissions before the year 2020 and the consumption of renewable energies to be 20% of total EU consumption (compared to 7% in 2006).[54] The accord indirectly acknowledged the role of nuclear energy — which is not commonly regarded as renewable, but emissions-free — in the reduction of the emission of greenhouse gases, allowing each member state to decide whether or not to use nuclear-generated electricity.[55]

Also, a compromise was reached to achieve a minimum quota of 10% biofuels in the total consumption of gasoline and diesel in transport in 2020.

Energy transition

Energiewende ("energy transition") designates a significant change in energy policy: The term encompasses a reorientation of policy from demand to supply and a shift from centralized to distributed generation (for example, producing heat and power in very small cogeneration units), which should replace overproduction and avoidable energy consumption with energy-saving measures and increased efficiency.

The key policy document outlining the *Energiewende* was published by the German government in September 2010, some six months before the Fukushima nuclear accident.[17] Legislative support was passed in September 2010. Important aspects include:

Key *Energiewende* policy targets (with actual figures for 2015)[19]

Target	2015	2020	2030	2040	2050
Greenhouse gas emissions (base year 1990)*	−27.2%	−40%	−55%	−70%	−80% to −95%
Renewable energy share of gross final energy consumption	14.9%	18%	30%	45%	60%
Renewable energy share of gross electricity consumption	31.6%	≥35%	≥50%	≥65%	≥80%
Primary energy consumption (base year 2008)	−7.6%	−20%	up	to	−50%
Gross electricity consumption (base year 2008)	−4.0%	−10%	up	to	−25%
*Provisional figure for 2015					

In addition, there will be an associated research and development drive.

The policy has been embraced by the German federal government and has resulted in a huge expansion of renewables, particularly wind power. Germany's share of renewables has increased from around 5% in 1999 to 22.9% in 2012, reaching close to the OECD average of 18% usage of renewables.[56] Producers have been guaranteed a fixed feed-in tariff for 20 years, guaranteeing a fixed income. Energy co-operatives have been created, and efforts were made to decentralize control and profits. The large energy companies have a disproportionately small share of the renewables market. Nuclear power plants were closed, and the existing nine plants will close earlier than planned, in 2022.

In May 2013, the International Energy Agency commended Germany for its commitment to developing a comprehensive energy transition strategy, ambitious renewable energy goals, and plans to increase efficient energy use and supported this approach. Nevertheless, the scale of Germany's energy policy ambitions, coupled with the large size and energy intensity of its economy, and its central location in Europe's energy system, mean further policy measures must be developed if the country's ambitious energy transition is to maintain a workable balance between sustainability, affordability, and competitiveness.[57]

Subsidies aimed at stimulating the growth of renewables have driven up consumer energy prices by 12.5% in 2013.[58] To date, German consumers have absorbed the costs of the *Energiewende*, but the IEA says the debate over the social and economic impacts of the new approach has become more prominent as the share of renewable energy has continued to grow alongside rising electricity prices. The transition to a low-carbon energy

sector requires public acceptance, and, therefore, retail electricity prices must remain at an affordable level. Presently, German electricity prices are among the highest in Europe, despite relatively low wholesale prices.[57] At the same time, the IEA said the new energy policy is based on long-term investment decisions, and a strong policy consensus in Germany in favour of large-scale renewable energy commercialisation exists.[57]

Ownership

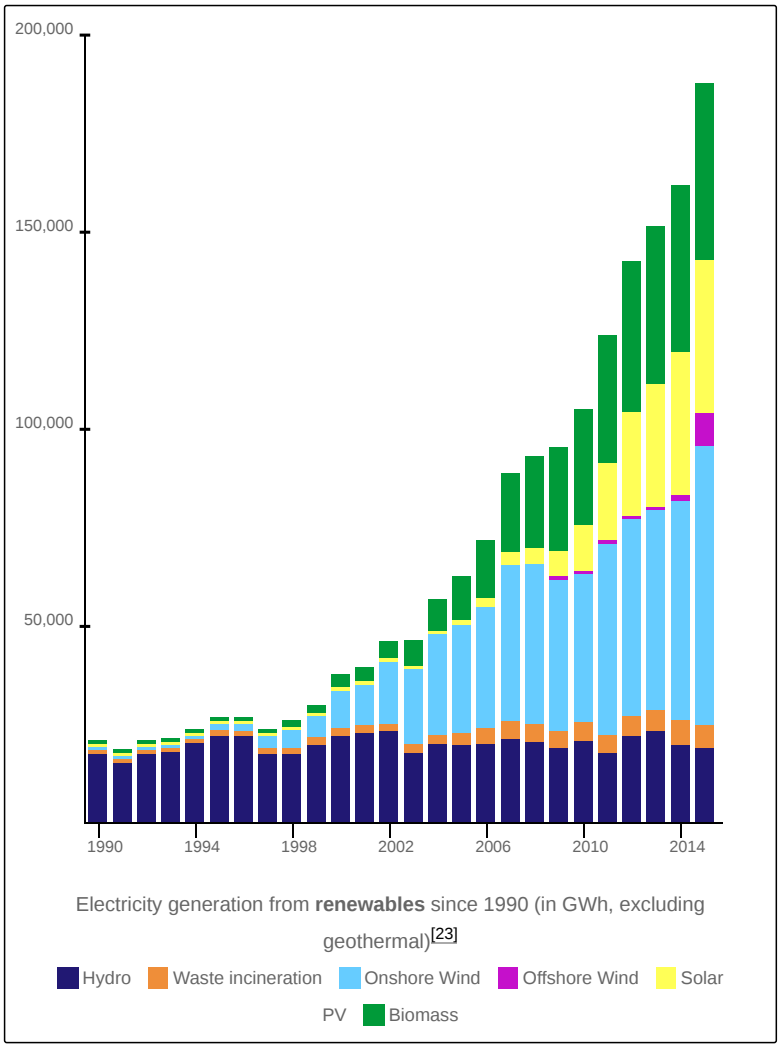
In Germany, almost half of renewable power capacity was citizen-owned as of 2013, and about 20 million Germans lived in so-called 100% renewable energy regions.[59]

Jobs

Estimated German jobs in renewable energy in 2012–2013 were about 370,000.[60]

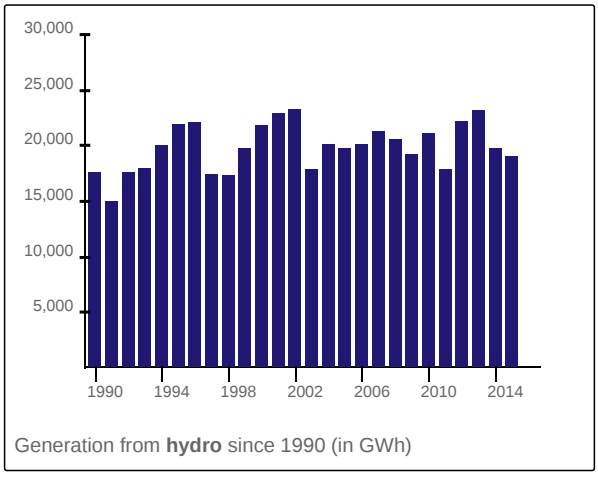
Statistics

Increases in installed renewable electric power capacity and generation in recent years is shown in the charts and table below:[23]

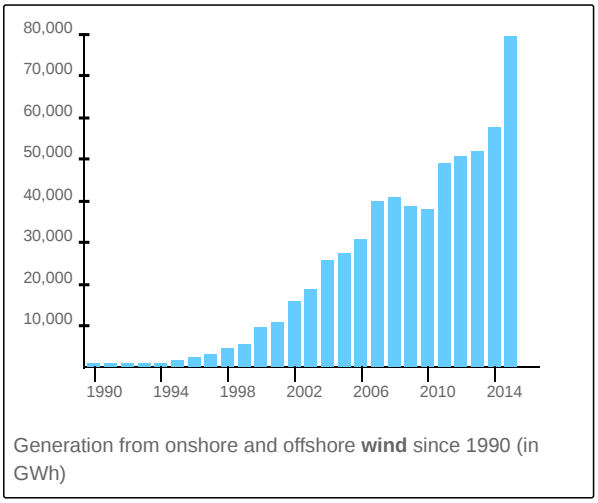


Year	Installed capacity [MW]	Electric gross generation in gigawatt-hours [GWh] by renewable sources since 1990								Share of gross electricity consumption [%]
		Hydro	Wind		Biomass[61]	Biogenic waste incineration[62]	Photovoltaics	Geothermal	Total generation	
			onshore	offshore						
1990	4,718	17,426	71	–	222	1,213	1	–	18,933	3.4
1991	4,826	14,891	100	–	260	1,211	1	–	16,463	3.1
1992	4,918	17,397	275	–	296	1,262	4	–	19,234	3.6
1993	5,190	17,878	600	–	432	1,203	3	–	20,116	3.8
1994	5,548	19,930	909	–	569	1,306	7	–	22,721	4.3
1995	6,223	21,780	1,500	–	662	1,348	7	–	25,297	4.7
1996	6,694	21,957	2,032	–	755	1,343	12	–	26,099	4.8
1997	7,255	17,357	2,966	–	876	1,397	18	–	22,614	4.1
1998	8,301	17,216	4,489	–	1,638	1,618	35	–	24,996	4.5
1999	10,155	19,647	5,528	–	1,845	1,740	30	–	28,790	5.2
2000	12,330	21,732	9,513	–	2,887	1,844	60	–	36,036	6.2
2001	15,157	22,733	10,509	–	3,355	1,859	76	–	38,532	6.6
2002	18,824	23,124	15,786	–	4,099	1,949	162	–	45,120	7.7
2003	22,099	17,722	18,713	–	6,603	2,238	313	–	45,589	7.6
2004	25,340	20,095	25,509	–	8,218	2,253	557	0.2	56,632	9.3
2005	29,040	19,638	27,229	–	11,102	3,252	1,282	0.2	62,503	10.2
2006	32,849	20,008	30,710	–	14,793	3,907	2,220	0.4	71,638	11.6
2007	36,046	21,170	39,713	–	19,832	4,531	3,075	0.4	88,321	14.2
2008	39,113	20,443	40,574	–	23,121	4,671	4,420	18	93,247	15.1
2009	47,958	19,031	38,610	38	26,308	4,323	6,583	19	94,912	16.3
2010	57,251	20,953	37,619	176	29,179	4,746	11,729	28	104,430	17.0
2011	67,684	17,671	48,314	577	32,136	4,755	19,599	19	123,071	20.3
2012	77,820	22,091	49,949	732	38,265	4,951	26,380	25	142,393	23.5
2013	84,330	22,998	50,803	918	40,112	5,415	31,010	80	151,336	25.1
2014	91,718	19,587	55,908	1,471	42,232	6,069	36,056	98	161,421	27.3
2015	99.368	18,977	70,922	8,284	44,553	5,768	38,726	134	187,364	31.5

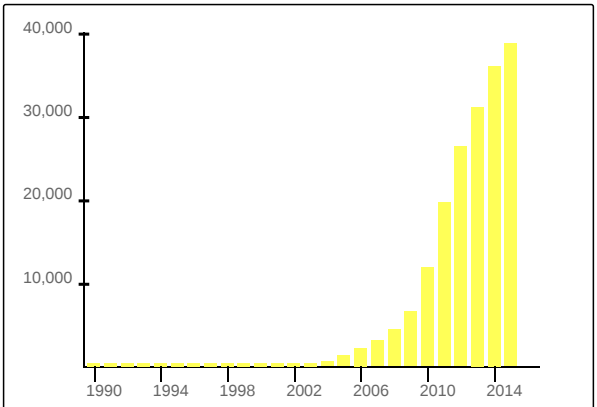
Source: Federal Ministry for Economic Affairs and Energy (German: *Bundesministerium für Energie und Wirtschaft*)[23]:6,7
Version: last published PDF data sheet as per December 2016[23]
Note: column "Biomass" contains all generated electricity from biomass, biofuels and biogas, excluding generation from biogenic waste incineration



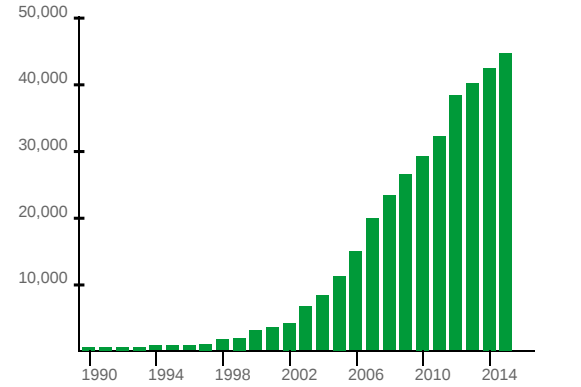
Generation from **hydro** since 1990 (in GWh)



Generation from onshore and offshore **wind** since 1990 (in GWh)



Generation from **solar PV** since 1990 (in GWh)



Generation from **biomass, biofuel, biogas** since 1990 (in GWh) (without biogenic waste incineration)

Computer models

The *Energiewende* has been subject to a number of computer studies. Most concentrate on electricity generation and consumption as this sector is undergoing a rapid transition in terms of technologies and institutions.

See also

2

Renewable energy portal

Germany portal

European Union portal

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62. Bionic share of energy generation from waste incineration

External links

- European Commission National Renewable Energy Action Plans (https://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans)
- European Commission renewable energy Progress Reports (https://ec.europa.eu/energy/en/topics/renewable-energy/progress-reports)
- European Commission National Energy Efficiency Energy Action Plans (https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans)

External links

- 2011 Renewable Energy Sources in Figures (http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Dokumente__PDFs_/broschuere_ee_zahlen_en_bf.pdf) from the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety - Renewable Energy (http://www.erneuerbare-energien.de/inhalt/3860/)
- For German Homeowners, Renewable Energy is No Longer a Choice (http://www.renewableenergyaccess.com/rea/news/story?id=50746)
- Climate, Energy, and Environment Overview from the German Department of State (http://www.germany.info/Vertretung/usa/en/06__Climate__Business__Science/01__Climate__Energy__Envir/Climate__Energy__Env.html)
- Official site about renewable Energy in the Emscher-Lippe-Region (http://energieatlas.org/)