Federal Ministry
for Economic Affairs
and Climate Action

80 MILLIONEN GEMEINSAM FÜR ENERGIEWECHSEL

Renewable energy sources in figures

National and International Development, 2022

bmwk.de

Imprint

Publisher
Federal Ministry for Economic Affairs and Climate Action (BMWK)
Public Relations
11019 Berlin
www.bmwk.de

Status
October 2023

This publication is available for download only.

Design
PRpetuum GmbH, 80801 Munich

Picture credit
Adobe Stock/reisezielinfo/title
istock/blacklight_trace/p. 11
istock/Mattes/p. 68
istock/bananajazz/p. 90

Central ordering service for publications of the Federal Government:
Email: publikationen@bundesregierung.de
Tel.: +49 30 182722721
Fax: +49 30 18102722721

Table of contents

List of figures

List of tables

Introduction

Dear readers,

With the new 2023 edition of the publication 'Renewable energy sources in figures – National and International Development', the Federal Ministry for Economic Affairs and Climate Action presents you with current data on the use of renewable energy in Germany, the EU and world-wide up to and including the year 2022.

The data presented in the following chapters show in detail how far we came with the expansion of renewable energy in Germany during 2022. They are therefore an important indicator of whether the course set so far in this legislative period is working to accelerate the expansion of renewable energy and where we still need to take further action to achieve a climate-neutral Germany.

In summary, the status of renewable energy uses in Germany for 2022 within the electricity, heat and transport sectors is as follows:

Electricity

Thanks to good wind conditions, a high number of sunshine hours and a significant increase in photovoltaic systems, electricity generation from renewable energy sources rose by 7% year-on-year to 254 terawatt-hours. With electricity consumption falling at the same time, the share of renewable energy in total electricity consumption rose by four and a half percentage points to 46.0%.

Heat

The use of heat from renewable energy sources increased significantly by 6% year-on-year to 211.7 terawatt-hours. In particular, the savings achieved in natural gas consumption in the heating sector as a result of the Russian war of aggression on Ukraine additionally led to a strong increase in the share of renewable energy sources in total heat consumption from 15.8% to 18.2%.

Transport

With biodiesel sales down slightly and a small increase in bioethanol sales, consumption of biofuels remained at the previous year's level. The use of electricity from renewable energy sources increased, particularly as a result of electromobility. This was offset by an overall increase in energy consumption in the transport sector, with the result that the share of renewable energy sources rose only minimally to 6.9%.

The expansion and use of renewable energy sources are associated with positive ecological and economic effects, which are as follows for the year 2022:

Renewable energy use cuts greenhouse gas emissions

The use of renewable energy sources reduces the burning of fossil fuels and thus avoids the associated emission of greenhouse gases. In 2022, a total of 237 million metric tonnes of CO_2-equivalent greenhouse gas emissions were prevented.

Investment and economic stimulus

Renewable energy sources are an important economic factor for Germany. In 2022, investments in new plants rose for the third year in a row to €21.9 billion. The economic impetus from the operation of total installed plants rose to €23.8 billion.

The most important data basis for this publication is the results of the Working Group on Renewable Energy Statistics (AGEE-Stat), which compiles the balance of renewable energy sources for Germany on behalf of the BMWK. Data from the German Environment Agency, the Federal Statistical Office, the Federal Network Agency, the Working Group on Energy Balances and many other sources are also included.

In addition to the data on the development of renewable energy, this publication also addresses the development of the political framework conditions such as for important laws and promotion programmes as well as in research and development.

Alongside information about developments in Germany, the second part of the brochure contains extensive data on the evolution of the use of renewable energy in the European Union as well as on the framework conditions and targets that the EU has set for itself. Finally, in the third part, the state of use of renewable energy worldwide is reviewed.

This brochure was prepared with the technical support of the Centre for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW), Stuttgart. All of the data listed is current as of the editorial deadline in October 2023 and is therefore still provisional in some places. Parallel to this brochure, the BMWK publishes on its website regularly updated time series and a wide range of graphs on the development of renewable energy in Germany from 1990 onwards. The complete data sets since 1990 can be found there while they are mostly presented in abbreviated form in this brochure for the sake of clarity, see Time series for the development of renewable energy sources in Germany and Graphics and diagrams.

A wide range of additional information on renewable energy and the energy transition in Germany can be found in the BMWK's online offering at BMWK and the Renewable energy information portal (in German only).

Your Federal Ministry for Economic Affairs and Climate Action

Berlin, October 2023

Working Group on Renewable Energy Statistics

Since February 2004, the Working Group on Renewable Energy Statistics (AGEE-Stat) has generated comprehensive and up-to-date statistics and data on the development of renewable energy sources in Germany. AGEE-Stat works on behalf of the Federal Ministry of Economics and Climate Protection. The AGEE-Stat's findings, especially in the national part, are the foundation of the data presented in this publication.

The AGEE-Stat is an independent expert body with members from various ministries, agencies and academic institutions. The following institutions are currently AGEE-Stat members:

- Federal Ministry for Economic Affairs and Climate Action (BMWK)
- the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV)
- the Federal Ministry of Food and Agriculture (BMEL)
- the German Environment Agency (UBA)
- the Federal Statistical Office (StBA)
- the Federal Network Agency (BNetzA)
- the Agency for Renewable Resources (FNR)
- the Center for Solar Energy and Hydrogen Research Baden-Württemberg (ZSW) as a representative of the Working Group on Energy Balances (AGEB).

AGEE-Stat is supported in its work by a consortium of scientific institutions. The project partners are the Leipzig Institute for Energy (IE Leipzig) as the coordinator, the Fraunhofer Institute for Solar Energy Systems (Fh-ISE), the German Biomass Research Center (DBFZ), the German Energy Agency (dena), the Ingenieurbüro Floecksmühle, the Hamburg Institute (HIC) and UL International GmbH.

The German Environment Agency in Dessau has been tasked with directing and coordinating the Working Group. The relevant office is located in Department V 'Climate change mitigation, Energy, German Emissions Trading Office' and is assisted by officials from Department V 1.8 'Energy data office of AGEE-Stat'.

AGEE-Stat's activities focus on continuously developing and assuring the quality of the statistics on the use of renewable energy sources in Germany. The Working Group also has the tasks of

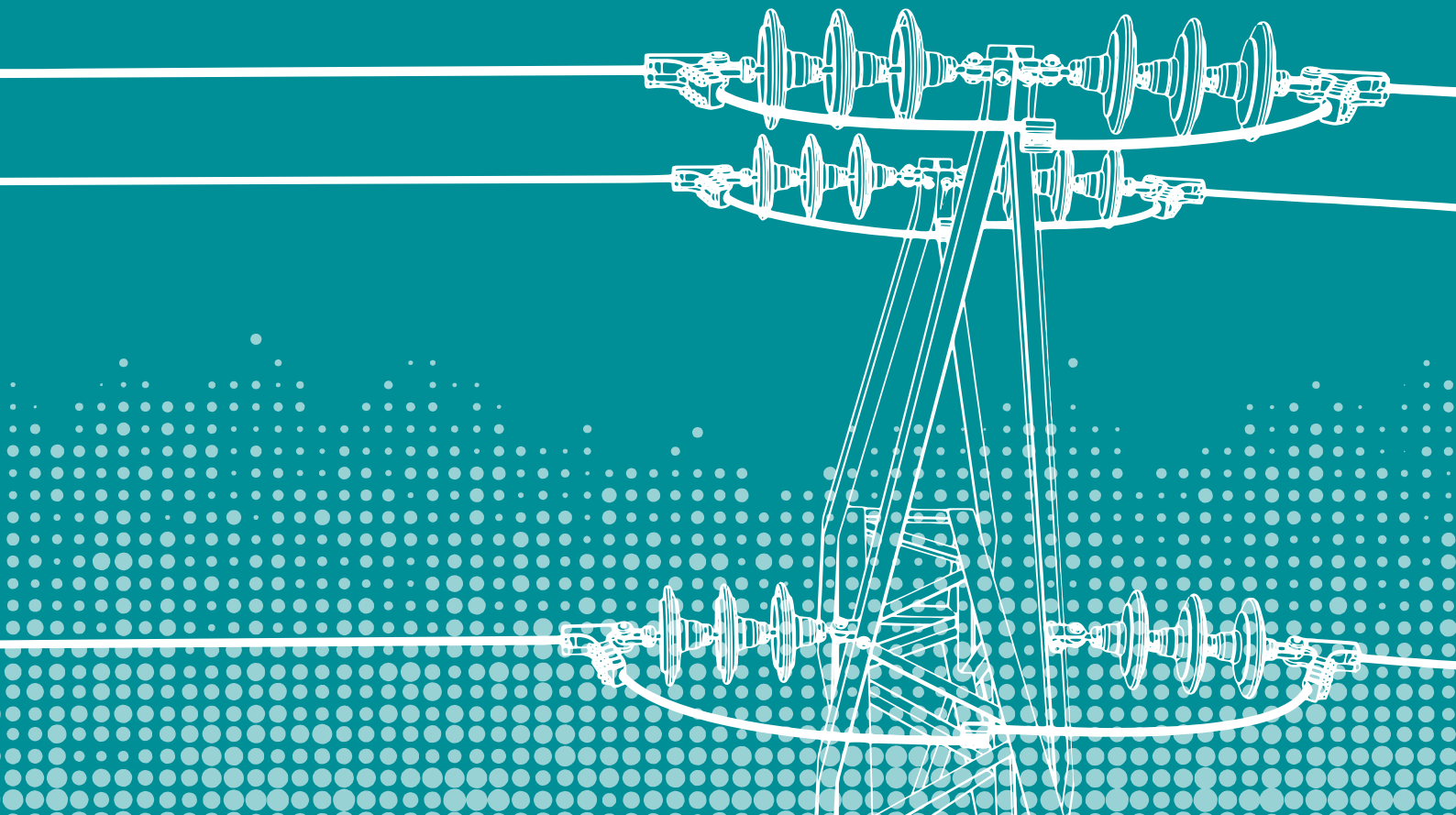
- creating a basis for meeting the Federal Government's various national, EU and international reporting obligations in the field of renewable energy,
- providing the public with information on renewable energy data and development.

AGEE-Stat conducts a wide range of research and publishes its findings in order to improve the data pool and the scientific calculation methods that are used. The group's work is supported by workshops and expert consultations on selected topics.

Further information on AGEE-Stat as well as up-to-date developments in renewable energy in Germany can be found as charts, time series, and monthly and quarterly reports at the Renewable energy information portal (in German only) of the Federal Ministry of Economics and Climate Protection and on the pages of the AGEE-Stat office in the German Environment Agency (in German only)

Part I: The energy transition in Germany

In its Federal Climate Change Act, Germany set itself the goal of achieving climate neutrality by 2045. In this respect, the energy transition, i.e. the conversion of our energy supply to renewable energy, accompanied by measures for the economical use of energy and efficiency improvements, is of central importance. A key element is the complete decarbonisation of our electricity supply with a milestone target of 80% renewable energy in electricity consumption by 2030. The energy transition also ensures that Germany's energy supply remains secure and affordable. The war of aggression by Russia on Ukraine has drastically shown us the risks associated with our dependence on energy imports. The energy transition is therefore key to Germany's path to an ecologically and economically successful future.



The year 2022 marked the first time that 46% of our gross electricity consumption came from wind, solar, biomass and hydropower. This demonstrates that we have already come a long way in the energy transition and the trend continues to be positive. The advancing energy transition in the electricity sector is highly visible with wind turbines rotating almost everywhere throughout the country, and the recent upswing in photovoltaics is evidenced by installation work on countless roofs.

However, in order to achieve the further milestones of the energy transition, the pace of expansion for wind energy and photovoltaics needs to be increased significantly. Moreover, the heating and transport sectors are still lagging far behind in the energy transition and climate protection. The federal government's policy is therefore very much aimed at taking corrective action. As early as 2021, essential measures to accelerate the expansion of renewable energy were launched under the so-called 'Easter Package'. Through this comprehensive set of immediate energy measures consisting of the amendment to the Renewable Energy Sources Act (RES), the Onshore Wind Energy Act, the Offshore Wind Energy Act (WindSeeG), the amendment to the Energy Industry Act (EnWG) and the Federal Nature Conservation Act (BNatSchG), the German government removed major obstacles and provided a noticeable boost to the expansion of renewable energy.

RES 2023 greatly increases expansion targets

The RES 2023, which came into force on 1 January 2023, will massively accelerate the expansion of renewable energy in the electricity sector. It targets an increase by 2030 of at least 80% of the electricity consumed in Germany to be from renewable energy sources while creating the framework conditions necessary for meeting this goal. The new expansion target translates into a near doubling of the share of renewable energy in under a decade. The task is even greater in absolute terms due to rising electricity consumption, resulting in part from the advancing electrification of industrial processes, heat supply and transport. By 2030, up to 600 terawatt hours of electricity should be generated from renewables – particularly wind and solar energy. In 2022, this figure was only around 254 terawatt hours. To achieve this ambitious goal, the expansion paths and tender volumes for wind energy and photovoltaics will be significantly increased until 2028/29. Tendering volumes for offshore wind will also be increased by a parallel amendment to the Offshore Wind Energy Act.

To accelerate the expansion of renewable energy in all areas of the law, the EEG 2023 established the principle that the use of renewable energy is within the overriding public interest and serves public safety. In addition, it contains numerous individual measures particularly for improving the framework conditions for the expansion of onshore wind and photovoltaics, for strengthening the acceptance and active participation of citizens in the energy transition and for setting the course for a climate-neutral electricity system of the future.

The EEG 2023 stipulates that a capacity of 115 gigawatts of onshore wind energy and 215 gigawatts of photovoltaics should be connected to the grid by the end of 2030. The EEG 2023 introduced crucial measures to strengthen the use of onshore wind energy. For example, the so-called reference yield model was adapted to enable the development of less windy locations and increase incentives for the expansion of wind energy, especially in southern Germany. Rules governing the financial participation of local authorities have been developed and are to be made standard practice in the future. In addition, the degression of maximum remuneration rates has been suspended and the Federal Network Agency has been given the option of adjusting these rates by up to 25%, for example, in the event of rising electricity generation costs.

Strategies for onshore wind and photovoltaics

In May 2023, the BMWK presented extensive strategies for the expansion of onshore wind energy and photovoltaics, the development of which was

accompanied by a public consultation process. The onshore wind energy strategy contains 12 packages of measures designed to ensure that expansion targets are achieved. The measures address energy industry, planning and licensing issues as well as socio-political aspects, including securing skilled labour and promoting technological development. Some of the measures are already being implemented while the rest are to be realised this year.

The BMWK has identified a total of 11 fields of action in its photovoltaic strategy to simplify and accelerate the expansion of photovoltaics in Germany. The envisaged measures address both concrete simplifications in the approval, construction and connection of PV systems as well as other topics such as the promotion of training and research. Most of the strategy is already being implemented through the solar package, which was approved by the Federal Cabinet in August. It provides for changes to the RES and the Energy Industry Act as well as to other legislation. These relate, for example, to the flexibilisation of the direct marketing obligation, the simplification of combining systems for roof installations and the introduction of shared building supply as a low-bureaucracy model for the delivery of PV electricity within a building. Further information on this can be found in the chapter 'Expansion of photovoltaics'.

Federal-Länder Cooperation Committee and expansion monitoring

The Federal Government and the Länder want to better coordinate the expansion of renewable energy as well as work together more closely. The RES provides for a Cooperation Committee of the responsible State Secretaries of the Federal Government and the Länder to coordinate the objectives and implementation status of the expansion of renewable energy sources. The Länder report annually to the Secretariat of the Cooperation Committee, which is based at the BMWK, on the status of the expansion of renewable energy sources for the previous year. The Committee analyses this information and submits an annual report to the Federal Government. Particular attention is paid to the status of land use designations and permits for onshore wind installations. One of the reasons for this is the Wind Energy Area Requirements Act (WindBG), which came into force on 1 February 2023, stipulates that 1.4% of Germany's land area must be designated for wind energy use by the end of 2027 and 2% by the end of 2032. The targets were distributed among the Länder considering their varying conditions and range from 0.5% for the city states to up to 2.2% for territorial states such as Lower Saxony, Brandenburg and Rhineland-Palatinate for the year 2032. The development in the individual Länder is therefore of particular importance here. On the basis of the Cooperation Committee's report, the Federal Government will inform the Bundestag and the heads of government of the Länder by the end of the year whether renewable energy sources are being expanded at the speed required to achieve the 80% target (80% share of renewable energy in gross electricity consumption) and if the interim targets set out in the RES are being met.

Energy transition in the heating sector

While the energy transition in the electricity sector is already well under way and many measures have been taken to accelerate it, there is still much work to be done in the heating sector. In addition, the energy price crisis in the winter of 2022/23 resulting from the Russian war of aggression against Ukraine has clearly demonstrated that we need to significantly reduce our dependence on energy imports. By revising the Building Energy Act (GEG) and the Federal Subsidy for Efficient Buildings (BEG), the Federal Government has initiated the transition to renewable energy for heating. In the future, newly installed heating systems will be required to use at least 65% renewable energy. The regulations governing the transition to renewable energy sources are to be introduced on a staggered basis for all new heating systems: for most new buildings on 1 January 2024 and for existing buildings or new buildings erected in gaps between buildings, no later than mid-2026 or 2028 when the deadlines for heat planning expire. Existing gas and oil heating systems functioning properly can, however, continue to be used. If a heating system is defective, it can also be repaired and then continue to be used.

As not every household is in a position to afford a new climate-friendly heating system, citizens are offered direct grants towards the investment costs and also now a supplementary loan via the proven federal subsidy for efficient buildings (BEG). Energy-efficient renovation measures and complete refurbishments will continue to be subsidised. Additionally, the Federal Ministry of Housing, Urban Development and Building (BMWSB), together with the BMWK, has launched the Heat Planning and Decarbonisation of Heating Networks Act (Wärmeplanungsgesetz – WPG). It was approved by the Federal Cabinet on 16 August 2023 and is expected to come into force soon. Next to the amended GEG, the Heat Planning Act forms the second pillar of an efficient and climate neutral heat supply of the future. Heat planning is an important instrument for the heating sector transition because it contributes to the coordination of local infrastructure development and creates a secure basis for planning. In addition to the mandatory nationwide introduction of heat planning, the WPG stipulates that heating networks must be supplied with at least 30% renewable energy sources or unavoidable waste heat by 2030, at least 80% as of 2040 and fully as of 2045.

Heat pumps will play an important role in the future fulfilment of legal obligations under the GEG. Therefore, a rapid market ramp-up of this technology is essential. The German government therefore launched a heat pump campaign in 2022 together with a broad alliance of business, industry, trade, research, science and the trade unions. The aim of which is to facilitate the installation of at least 500,000 heat pumps annually starting in 2024. On 16 November 2022, the key issues paper for the 2nd summit of the campaign initiated the process of drawing up a concrete short-term roadmap, available since February 2023 and being developed on an ongoing basis. An initial update of the roadmap was published in September 2023, illustrating the variety of measures already initiated and implemented. Since April 2023, the Federal Development Programme for Heat Pumps (BAW) has been supporting the qualification of skilled workers.

Electromobility: The key to climate protection in transport

Electromobility is the key to climate-friendly mobility globally. Germany is set to become the leading market for electromobility with the Federal Government's goal of at least 15 million fully electric cars on the roads and 1 million publicly accessible charging stations by 2030. By the end of 2022, there were already 1.9 million electric vehicles on the road in Germany, over 830,000 newly registered in 2022 alone. A key element in promoting the ramp-up of electromobility is the environmental bonus, a purchase premium that is jointly funded by the Federal Government and car manufacturers. Since 1 January 2023, the Federal Government has restructured this funding by ending the environmental bonus for plug-in hybrids and concentrating on purely battery electric vehicles. With the Charging Infrastructure Masterplan II, the German government has also developed an overall strategy for the expansion of the charging infrastructure. In order to efficiently coordinate all included measures, the BMWK and BMDV have set up an inter-ministerial steering group (ISLa) whose most important task is to improve the connection between the expansion of the charging infrastructure and the optimisation of the associated electricity grids. Electromobility is not only important for transport, but for the energy transition as a whole. As part of the coupling of the charging infrastructure with the electricity grids, it will be possible to charge e-cars at low cost primarily when there is a surplus of volatile wind and solar power, and to feed electricity back into the grid bidirectionally at other times. Hence, smart and bidirectional charging infrastructures will have an essential complementary function in the renewable electricity system.

Update of the national hydrogen strategy

Green or so-called low-carbon hydrogen plays an important role in the decarbonisation of our energy system for industry, heavy commercial

vehicles and also in aviation and shipping, especially as fuel produced via the power-to-liquid process. For the electricity sector, a smart infrastructure will also make an important contribution to security of supply. The National Hydrogen Strategy adopted in 2020 has created a framework for investment in hydrogen infrastructure, thereby providing an important impetus for the establishment of a German hydrogen economy. In July 2023, the Federal Government decided to adapt the strategy to meet the heightened level of ambition in climate protection and new challenges on the energy market. It sets the next step in the market ramp-up: from research and demonstration to large-scale production of green hydrogen. The 2030 target for domestic electrolysis capacity has been increased from 5 gigawatts to at least 10 GIGAWATTS. In addition, by 2027/2028 in Germany, a hydrogen start-up network of more than 1,800 kilometres of converted and newly built hydrogen pipelines will be established. Germany will become a leading provider of hydrogen technology by 2030 due to the impetus provided by the updated National Hydrogen Strategy.

The expansion of renewable energy sources must be continuously monitored in order to make targeted adjustments by taking appropriate measures at any time. This publication aims to create transparency with the data compiled below. The data published here also provide an important basis for the fulfilment of numerous reporting obligations of the Federal Government on renewable energy at national, European and international level.

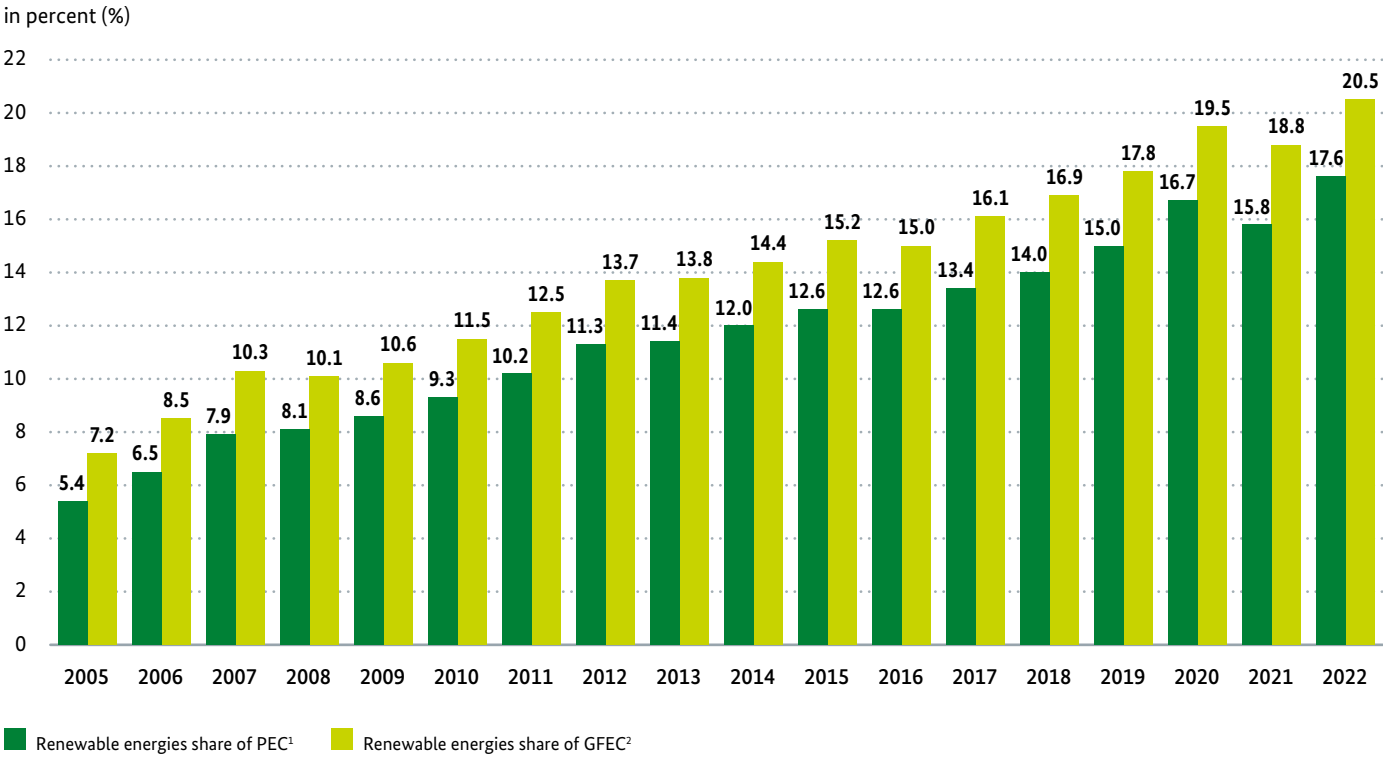
Table 1: Renewable energy in Germany: The status quo

Categories	2021	2022	Target 2030
Renewable energy share		**[%]**	
of gross final energy consumption	18.8	20.5	45[2]
of gross electricity consumption	41.5	46.0	80[3]
of final energy consumption in heating/cooling[1]	15.8	18.2	49[4]
of final energy consumption in transport	6.8	6.9	29[5]
of primary energy consumption	15.8	17.6	-39.3[6]
Avoidance of greenhouse gas emissions through the use of renewable energy sources		**million t CO_2-eq.**	
Total greenhouse gas avoidance	219.1	236.6	–
of which through electricity with remuneration under the EEG Act	142.2	154.7	–
Economic impetus through the use of renewable energy sources		**billion €**	
Investment in the construction of renewable energy plants	14.5	21.9	–
Costs/Revenues from the operation of renewable energy plants	20.3	23.8	–

1 Incl. district heating consumption
2 Target value according to 2023 updated EU Renewable Energy Directive (RED II); as before, a binding 42.5% is to be provided by the member states.
There is an additional indicative target of 2.5%. This 'top-up' is to be achieved through further voluntary contributions by the member states or pan-European measures. [1]
3 Federal government target according to the Renewable Energy Sources Act (RES 2023) [2]
4 Target value according to 2023 updated EU Renewable Energy Directive (RED II)
5 Target value according to the 2023 updated EU Renewable Energy Directive (RED II). The new binding sub-targets in transport include a combination of electricity-based renewable fuels (RFNBOs) and advanced biofuels.
This sub-target is 5.5%, of which 1% is to be covered by hydrogen and other electricity-based fuels (RFNBOs).
6 Target value in accordance with the Energy Efficiency Act (EnEfG): The target is to reduce primary energy consumption by 2030 compared to 2008 by at least 39.3% to a primary energy consumption of 2,252 TWh.

Sources: Federal Ministry for Economic Affairs and Climate Action (BMWK) based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany" [3], provisional figures

Figure 1: Shares of renewable energy sources in gross final energy consumption (GFEC) and primary energy consumption (PEC)



1 Reduction in renewables' share in primary energy consumption due to change in methodology from 2012 onwards, preceding years not yet revised.

2 Method for calculating share of renewable energy in gross energy consumption according to the Federal Government's "Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung" (in German only) does not take account of special calculation rules set out in EU Directive 2009/28/EC. For more details on the methodology for calculating the shares of renewables in gross final energy consumption, see the 'Information on methodology' section.

According to the updated EU Renewable Energy Directive (RED II) [1], renewable energy must account for 45% of gross final energy consumption by 2030.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany" ([3], Table 2); provisional figures

Expansion of renewable energy

Electricity

Share of renewable energy increases to 46%

While the share of renewable energy sources in gross electricity consumption fell in the previous year for the first time since the start of the energy transition, it rose again sharply by four and a half percentage points to 46.0% in 2022 (2021: 41.5%). The upward trend was due in part to the unusually high number of sunshine hours combined with a further acceleration in the expansion of photovoltaics. As a result, solar power generation increased by 19% or 9.8 terawatt-hours compared to the previous year. In addition, wind conditions were also better than in the previous year, meaning that wind power generation increased by 10.6 terawatt-hours or 9%. In contrast, the generation of electricity from hydropower declined significantly due to drought.

Overall, the generation of electricity from renewable energy sources recorded an increase of 7.3% to 254.2 terawatt-hours (2021: 236.9 terawatt-hours). At the same time, total gross electricity consumption fell by 3.4% year-on-year to 552.1 terawatt-hours (2021: 571.5 terawatt-hours) due to energy-saving measures in the wake of the Russian war of aggression against Ukraine, which led to an additional increase in the share of gross electricity consumption from renewable energy sources.

Sluggish wind energy expansion

In 2022, the installed capacity of onshore wind energy grew by 2,110 megawatts, an increase of 30% compared to the previous year (2021: 1,628 megawatts). This means that wind energy expansion has increased for the third year in a row after the low point of 2019. Nevertheless, the figure is still far removed from the future annual expansion volumes necessary to achieve the 80% target for renewable energy in gross electricity consumption by 2030. At the end of 2022, 58,014 megawatts of onshore wind energy capacity had been installed across Germany. Following the stagnation in expansion of offshore wind energy during the previous year, an increase of 342 megawatts capacity was recorded in 2022. Accordingly, installed output rose to 8,149 megawatts.

Significant increase in wind power generation continues

Electricity generation from wind energy benefited primarily from improved wind conditions. Following a significant slump in the previous year due to very low wind levels, onshore wind power generation increased again by 11% to 99.7 terawatt-hours (1 terawatt-hour = 1 billion kilowatt-hours) (2021: 89.8 terawatt-hours). Offshore wind power generation increased only slightly by 3% to 25.1 terawatt-hours (2021: 24.4 terawatt-hours). In 2022, a total of 124.8 terawatt-hours of electricity were generated from wind, a solid 9% more than in the previous year (2021: 114.2 terawatt-hours). Wind energy covered 22.6% of gross electricity consumption, and thereby remains the most important source of electricity in Germany.

Table 2: Renewables-based gross electricity generation in 2021 and 2022

	Renewable energy sources 2021		Renewable energy sources 2022	
	Gross electricity generation (GWh)[4]	Share of gross electricity consumption[5] (%)	Gross electricity generation (GWh)[4]	Share of gross electricity consumption[5] (%)
Hydropower[1]	19,657	3.4	17,625	3.2
Onshore wind energy	89,795	15.7	99,692	18.1
Offshore wind energy	24,374	4.3	25,124	4.6
Photovoltaic	50,472	8.8	60,304	10.9
Biogenic solid fuels[2]	10,738	1.9	10,254	1.9
Biogenic liquid fuels	210	0.04	97	0.02
Biogas	30,552	5.3	30,469	5.5
Biomethane	3,273	0.6	3,098	0.6
Sewage gas	1,576	0.3	1,553	0.3
Landfill gas	229	0.04	201	0.04
Biogenic fraction of waste[3]	5,792	1.0	5,562	1.0
Geothermal energy	244	0.04	206	0.04
Total	**236,912**	**41.5**	**254,185**	**46.0**

1 For pumped-storage power plants only electricity generation from natural inflow

2 Including sewage sludge

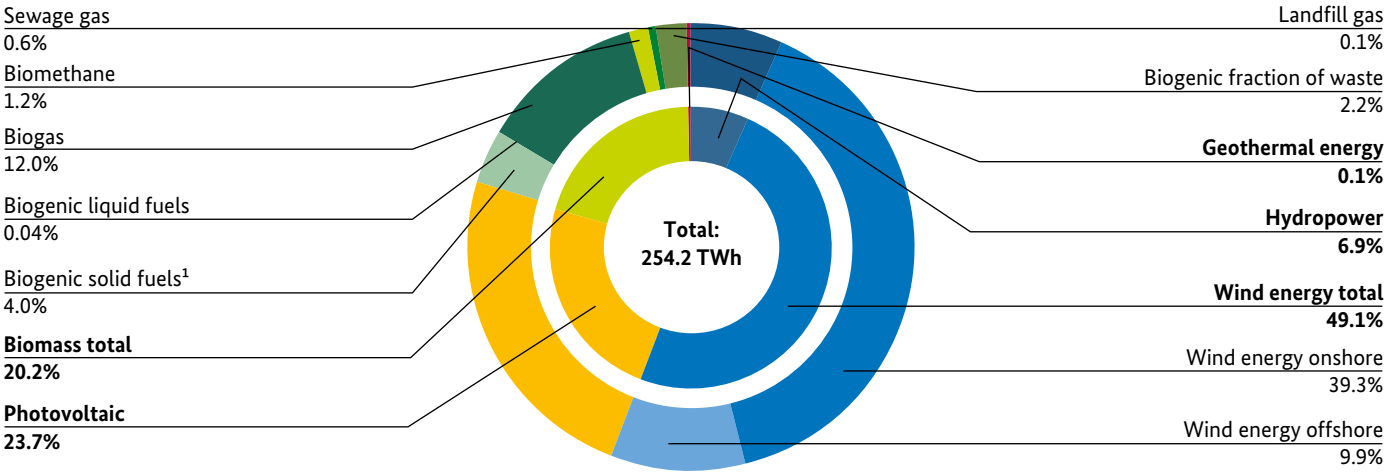
3 Biogenic share of waste estimated at 50% in waste incineration plants

4 1,000 GWh = 1 TWh

5 Based on gross electricity consumption, 2021: 571,5 TWh, 2022: 552,1 TWh ([3], AGEE-Stat time series: Table 7)

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3); provisional figures

Figure 2: Renewables-based gross electricity generation, 2022



1 Including sewage sludge

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3); provisional figures

Table 3: Electricity generation from renewable energy sources

	Hydro-power[1]	Onshore wind energy	Offshore wind energy	Photo-voltaics	Biomass[2]	Geothermal energy	Total gross electricity generation	Share of gross electricity generation[4]	Share of gross electricity consumption[4]
	(GWh)[3]						(GWh)[3]	(%)	(%)
2005	19,638	27,774	0	1,308	14,818	0,2	**63,538**	**10.2**	**10.3**
2006	20,031	31,324	0	2,265	19,175	0,4	**72,795**	**11.4**	**11.7**
2007	21,170	40,507	0	3,137	25,185	0,4	**89,999**	**14.0**	**14.4**
2008	20,443	41,385	0	4,508	28,752	18	**95,106**	**14.8**	**15.3**
2009	19,031	39,382	38	6,715	31,789	19	**96,974**	**16.3**	**16.6**
2010	20,953	38,371	176	11,963	34,955	28	**106,446**	**16.8**	**17.2**
2011	17,671	49,280	577	19,991	38,109	19	**125,647**	**20.5**	**20.6**
2012	21,755	50,948	732	26,744	44,886	25	**145,090**	**23.0**	**23.8**
2013	22,998	51,819	918	30,621	47,241	80	**153,677**	**24.0**	**25.3**
2014	19,587	57,026	1,471	35,448	50,111	98	**163,741**	**26.1**	**27.5**
2015	18,977	72,340	8,284	38,076	52,263	133	**190,073**	**29.3**	**31.6**
2016	20,546	67,650	12,274	37,556	52,905	175	**191,106**	**29.4**	**31.8**
2017	20,150	88,018	17,675	38,761	52,907	163	**217,674**	**33.3**	**36.2**
2018	18,098	90,484	19,467	44,320	52,734	178	**225,281**	**35.0**	**37.9**
2019	20,135	101,150	24,744	45,221	52,152	197	**243,599**	**39.9**	**42.2**
2020	18,721	104,796	27,306	49,496	52,989	231	**253,539**	**44.0**	**45.5**
2021	19,657	89,795	24,374	50,472	52,370	244	**236,912**	**40.2**	**41.5**
2022	17,625	99,692	25,124	60,304	51,234	206	**254,185**	**43.9**	**46.0**

1 For pumped-storage power plants only electricity generation from natural inflow

2 Solid and liquid biomass, biogas, biomethane, landfill gas and sewage gas, sewage sludge and biogenic share of waste (estimated at 50% in waste incineration plants)

3 1,000 GWh = 1 TWh

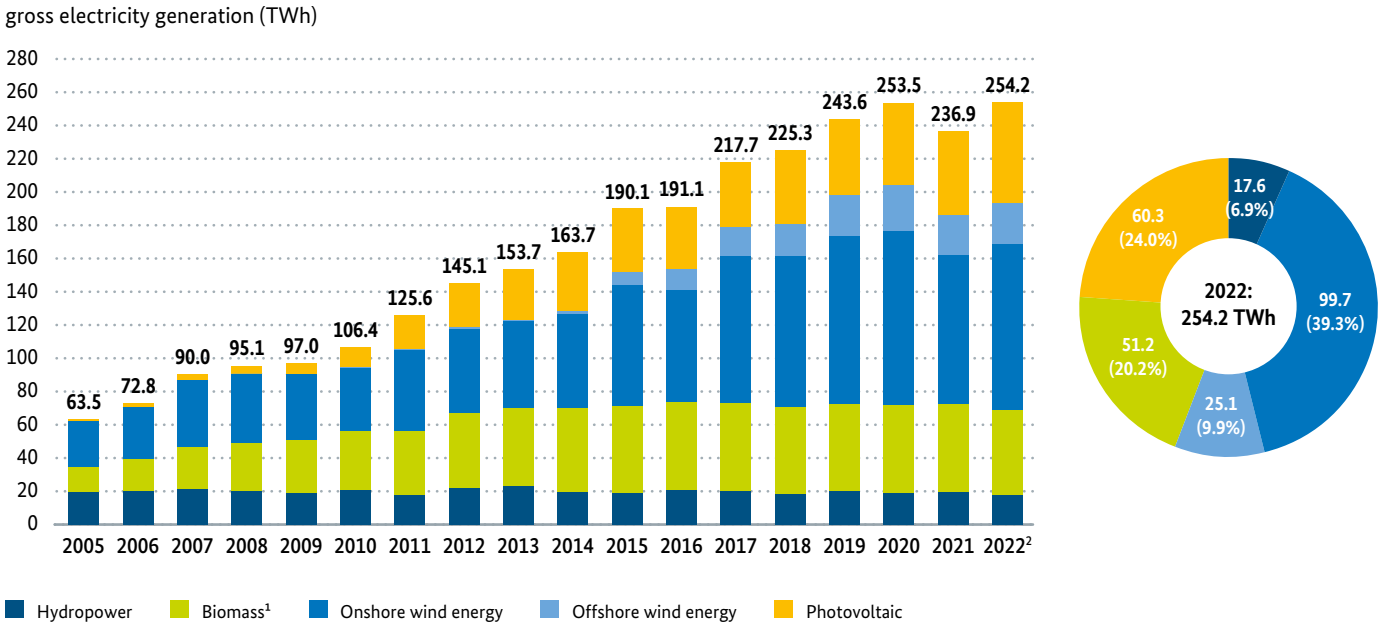
4 AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 7)

The share of renewable energy sources in gross electricity generation includes the total amount of electricity generated in Germany (conversion output according to the German energy balance), i.e. including exported electricity that is not available for use in Germany.

The share of gross electricity generation is an alternative calculation to the commonly used share of total domestic gross electricity consumption. National and international reporting obligations use the share of gross electricity consumption because this enables cross-country comparisons without having to consider imported or exported electricity volumes.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3); provisional figures

Figure 3: Gross electricity generation from renewable energy sources



1 Solid and liquid biomass, biogas, biomethane, landfill gas and sewage gas, sewage sludge and biogenic share of waste

2 Electricity generation of the respective technologies in previous years: see Table 3

Geothermal electricity generation not shown due to low electricity volumes.
The electricity volumes for the years 2005 – 2022 are shown. According to the Renewable Energy Sources Act (RES), the target for gross electricity generation from renewable energy sources in 2030 is 600 TWh [2].

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3); provisional figures

Strong growth in Photovoltaics

The years long upward trend in photovoltaic installations gained further momentum in 2022. With 7,441 megawatts, 30% more photovoltaic capacity was added than in the previous year (2021: 5,724 megawatts). This brought expansion closer to the record years of 2011/2012, when around 8,000 megawatts per year were newly installed. Nevertheless, a much greater expansion of up to 22,000 megawatts per year will be required in the coming years to achieve renewable energy targets in the electricity sector.

Of the newly installed capacity in 2022, 54% was attributable to smaller, primarily building-bound systems with a capacity of less than 750 kilowatts or up to 1 megawatt (from July 2022) which receive a guaranteed feed-in tariff. A further 34% was accounted for by larger systems awarded contracts through RES tenders and therefore also entitled to fixed feed-in tariffs. The remaining 12% were installed outside the scope of the RES and without a fixed remuneration claim.

At the end of 2022, photovoltaic systems with a total capacity of 67,479 megawatts were installed in Germany. Compared to the previous year, output increased by 12%, while the year-on-year increase in electricity generation was higher at 19% or 60.3 terawatt-hours (2021: 50.5 terawatt-hours). A very high number of sunshine hours in the summer half-year (May to October) of 2022 was the reason for this. The average global irradiation across Germany was 23% higher in May, 19% higher in July and as much as 30% higher in August than in the previous year.

Biomass electricity generation remains stable

In recent years, marked increases in electricity generation capacity from biomass have been recorded. These served primarily the 'overbuilding' of existing biogas plants, whereby an increase in installed capacity from stored biogas on site enables flexible, needs-based electricity generation. However, a saturation effect can be observed here as the corresponding capacity additions have

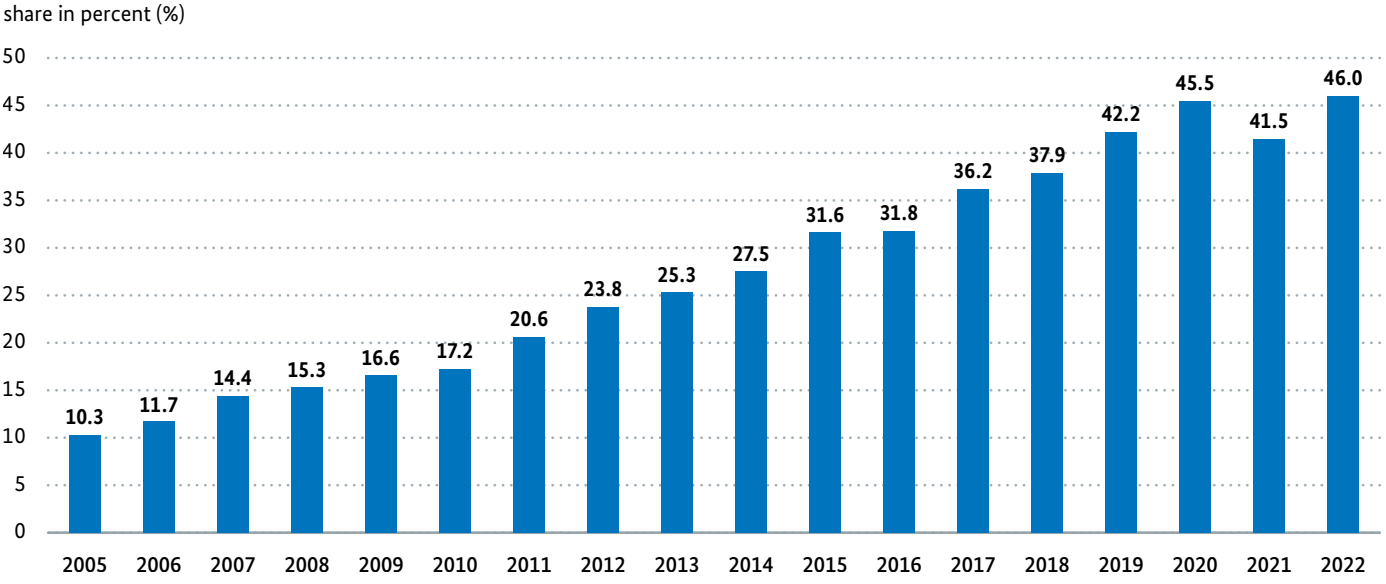
fallen sharply for the second year in a row and amounted to only around 60 megawatts in 2022.

Biomass continues to be a stable pillar in the renewable electricity mix and has contributed more or less constant amounts of electricity for years. The degree of flexibilisation is increasing, albeit slowly. Biogas, biomethane, solid and liquid biomass, landfill and sewage gas and the biogenic share of municipal waste together generated 51.2 terawatt-hours of electricity in 2022, slightly less than in the previous year (2021: 52.4 terawatt-hours). Biogas and biomethane accounted for the largest share of this at 33.6 terawatt-hours (2021: 33.8 terawatt-hours). Overall, biomass covered 9.2% of Germany's gross electricity consumption.

Hydropower ebbing due to drought

Extreme drought conditions in 2022 have had a significant impact on electricity generation from hydropower. The lowest value in 24 years came in at 17.6 terawatt-hours, 10% fewer than in the previous year (2021: 19.7 terawatt-hours) despite higher levels of installed hydropower capacity. The share of hydropower in total gross electricity consumption fell to 3.2% (2021: 3.4%). Geothermal energy continued to make only a marginal contribution to our electricity supply at 0.21 terawatt-hours.

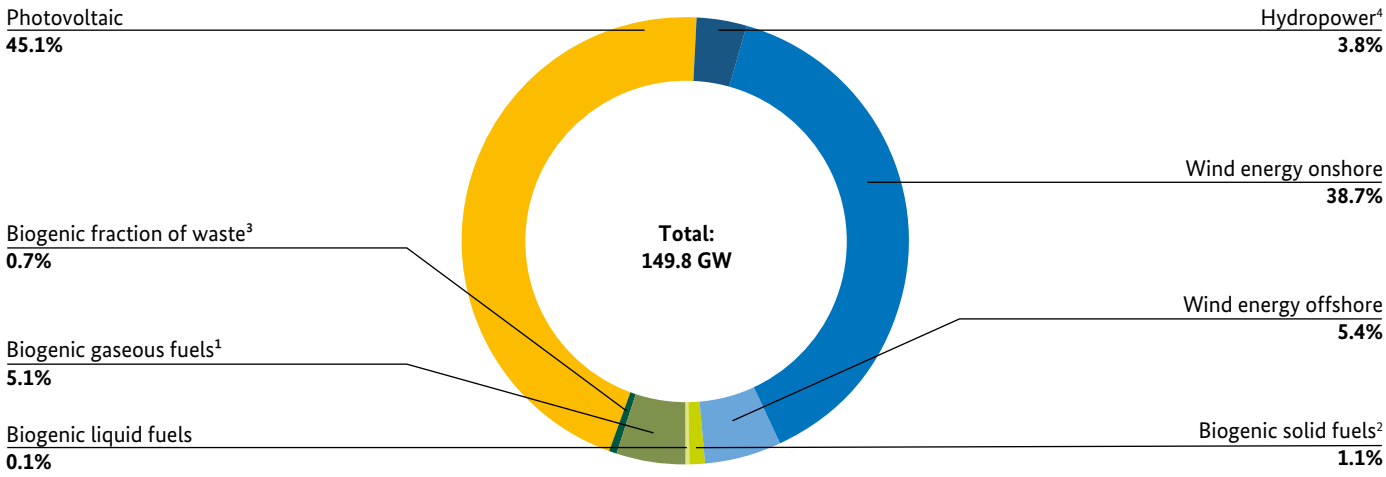
Figure 4: Share of renewables-based electricity generation in gross electricity consumption



According to the Renewable Energy Sources Act (RES) 2023, the share of renewable energy sources in gross electricity consumption should be at least 80% by 2030.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 2); provisional figures

Figure 5: Installed power generation capacity based on renewable energy source [GW], 2022



Geothermal power plants are not shown here because of the very small share involved.

1 Biogas, biomethane, landfill gas and sewage gas

2 Incl. sewage sludge, excluding biogenic share of waste

3 Incl. biogenic share of waste (estimated at 50% in waste incineration plants)

4 Installed hydropower capacity includes pumped-storage power plants with natural inflow

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 4); provisional figures

Table 4: Installed power generation capacity based on renewables

	Hydropower[1]	Onshore wind energy	Offshore wind energy	Photovoltaics	Biomass[2]	Geothermal energy	Total capacity
				(MW)[3]			
2005	5,210	18,248	0	2,056	2,939	0	**28,453**
2006	5,193	20,474	0	2,899	3,647	0	**32,213**
2007	5,137	22,116	0	4,170	4,006	3	**35,432**
2008	5,164	22,794	0	6,120	4,371	3	**38,452**
2009	5,340	25,697	35	10,566	5,593	8	**47,239**
2010	5,407	26,823	80	18,006	6,222	8	**56,546**
2011	5,625	28,524	188	25,916	7,162	8	**67,423**
2012	5,607	30,711	268	34,077	7,467	19	**78,149**
2013	5,590	32,969	508	36,710	7,966	30	**83,773**
2014	5,580	37,620	994	37,900	8,204	33	**90,331**
2015	5,589	41,297	3,283	39,224	8,429	34	**97,856**
2016	5,629	45,283	4,152	40,679	8,659	38	**104,440**
2017	5,627	50,174	5,406	42,293	8,982	38	**112,520**
2018	5,347	52,328	6,393	45,158	9,662	42	**118,930**
2019	5,396	53,187	7,555	48,864	9,995	47	**125,044**
2020	5,454	54,276	7,807	54,314	10,320	47	**132,218**
2021	5,489	55,904	7,807	60,038	10,420	54	**139,712**
2022	5,621	58,014	8,149	67,479	10,460	59	**149,782**

The information on installed capacity relates to the figure at the end of the year.

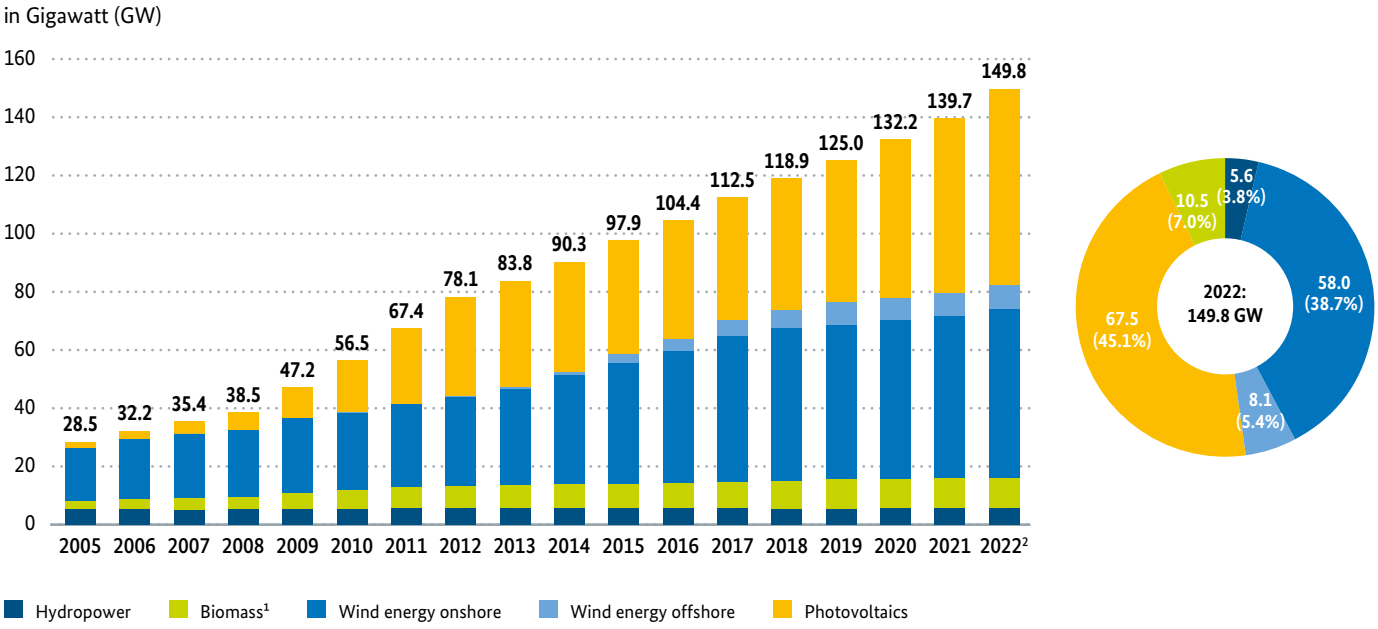
1 Installed hydropower capacity includes pumped-storage power plants with natural inflow.

2 Solid and liquid biomass, biogas, biomethane, landfill gas, sewage gas and sewage sludge, including the capacity of all waste incineration plants for renewable and non-renewable waste. For the time series, 50% of the total waste incineration capacity shown as a renewable output.

3 1,000 MW = 1 GW

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 4); provisional figures

Figure 6: Installed power generation capacity based on renewables



1 Solid and liquid biomass, biogas, biomethane, landfill gas, sewage gas and sewage sludge, including the capacity of all waste incineration plants for renewable and non-renewable waste. For the time series, 50% of the total waste incineration capacity shown as a renewable output.

4 Electricity generation of the respective technologies in previous years: see table 4, Geothermal power plants are not shown here because of the very small share involved. See table 4

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 4); provisional figures

Installed capacity and electricity generation

Figure 7 shows the development of installed capacity and electricity generation of the individual renewable energy sources over the past five years. Here, the differing ratios of installed capacity to electricity generation for the individual energy sources are clearly evident. In 2022, the output of photovoltaics was already significantly higher than that of onshore wind energy (58.0 gigawatts) at 67.5 gigawatts, but at 60.3 terawatt-hours, around 40% less electricity was generated from photovoltaic systems than from onshore wind energy systems (99.7 terawatt-hours).

This is made even more clear in figure 8. For 2020, 2021 and 2022, the installed capacity and quantities of electricity generated from the various renewable energy sources are directly compared as percentages in bar charts. While the two shares for onshore wind energy are roughly equal, the share of photovoltaic installed capacity is much higher than its electricity generation. However, for biomass, offshore wind energy and hydropower, the reverse is true, i.e. the share of electricity generation is significantly higher than the share of installed capacity.

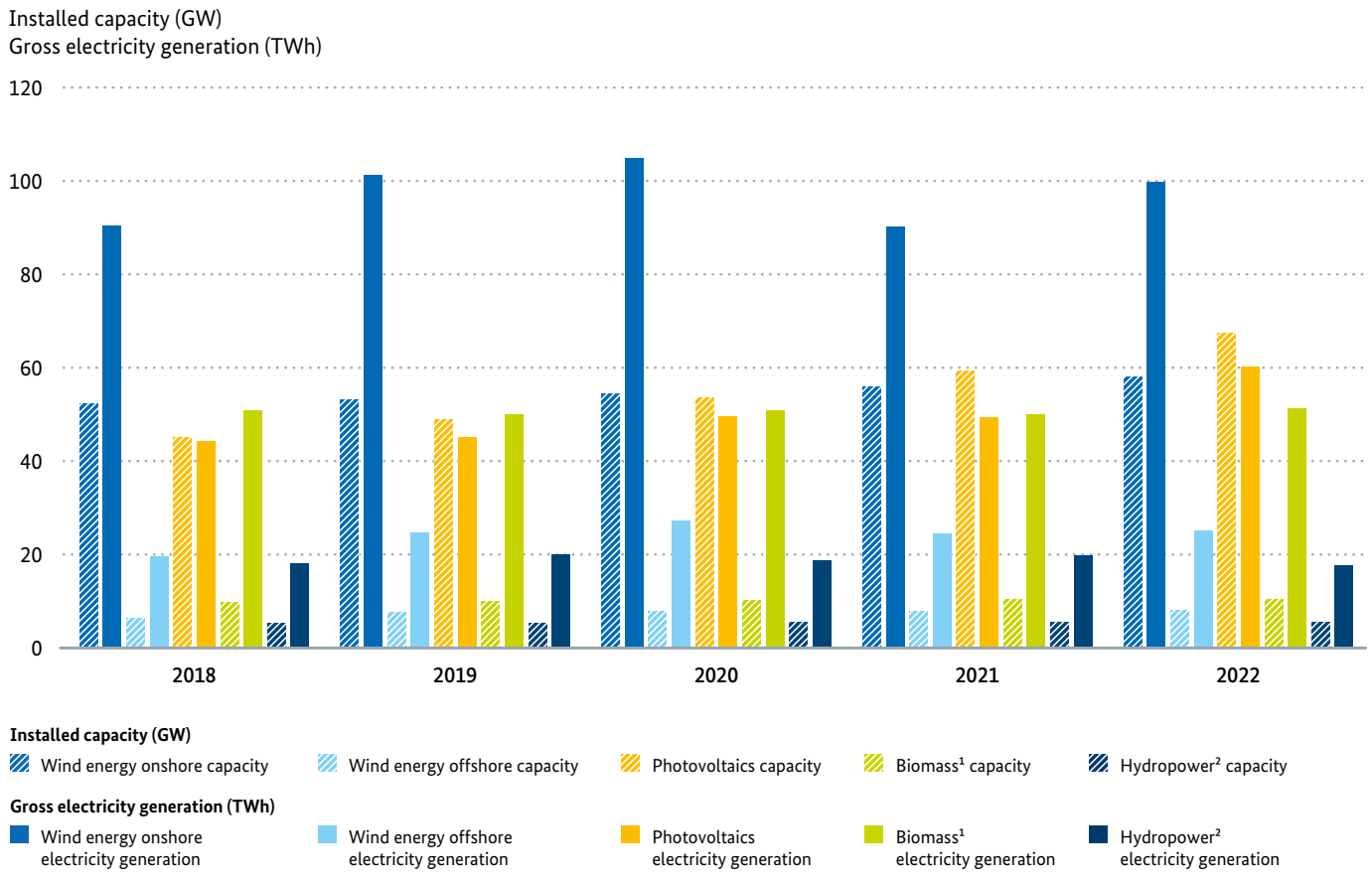
The reason for this in the case of PV and wind energy installations is the availability of natural resources (sunshine, wind) and the corresponding technical potential to convert these resources into electricity. This can be expressed in terms of a technology-specific parameter that captures both effects, the so-called full-load hours . They are an indicator of the utilisation of the capacity of electricity generation plants. In Germany, the number of full-load hours[1] for the use of renewable energies varies considerably: while photovoltaics has between 900 and 1,000 full-load hours per year, averaged over all locations, onshore wind energy has between 1,600 and 2,000, and wind energy at

1 **Full load hours** are a measure that describes the utilisation of a power generation plant. The full load hours are calculated by dividing the amount of electricity generated in a year by the nominal output of the system. The full load hours indicate the number of hours in a year in which a system would have to run at nominal output (i.e. full load) in order to provide the actual annual amount of electricity generated.

sea between 3,000 and 4,000, depending on the location. Thus, per installed capacity, onshore wind energy supplies around twice as much electricity as photovoltaics, and offshore wind energy more than three times as much. An advantage of electricity generation from wind energy is also the more even flow throughout the day, whereas photovoltaic systems do not feed in at night. When viewed over the course of a year, the two energy sources complement each other well, as photovoltaic systems produce most of their energy in the summer half-year, while wind turbines do so in the winter half-year. Plus, there is often less wind in sunny weather and more in cloudy weather.

In the case of hydropower, the full load hours are between 3,100 and 3,600 per year, depending on precipitation conditions. Biomass plants currently have around 5,000 full load hours. Here, the utilisation of the plant capacity depends mainly on the operation and only to a small extent on the availability of resources. Since the plants are increasingly operated according to demand and no longer at permanent full load in the course of the so-called overbuilding of capacity (e.g. increase in capacity with constant biomass supply), the full load hours are currently showing a downward trend. This enables flexible power generation and adaptation to the fluctuating power feed-in from wind and solar energy, which is dependent on natural supply.

Figure 7: Gross electricity generation and installed capacity per energy source

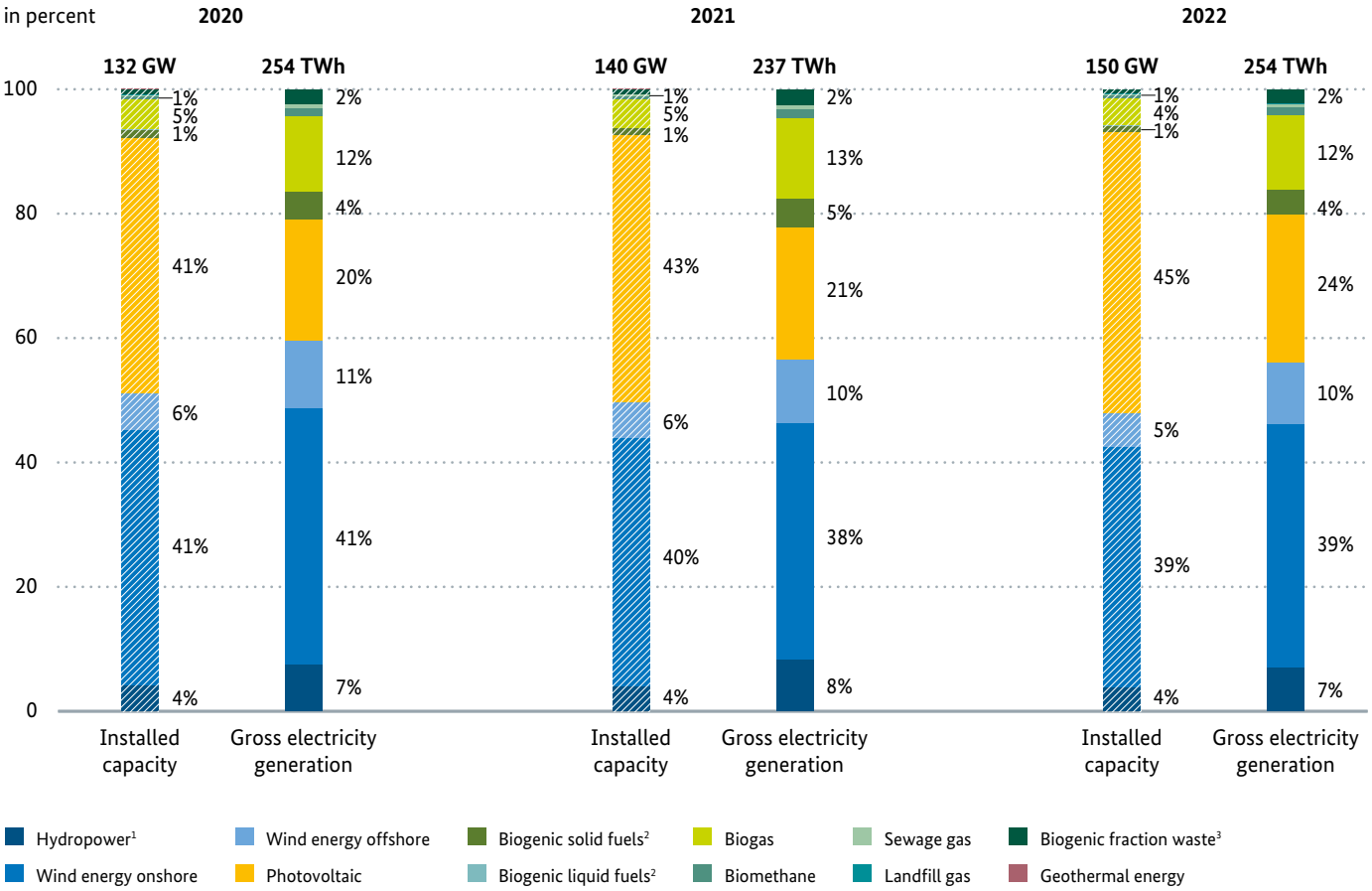


1 Output and gross electricity generation of solid and liquid biomass, biogas, biomethane, landfill gas, sewage gas and sewage sludge. Capacity of all waste incineration plants for renewable and non-renewable waste taken into account. In this context, 50% of the total waste incineration capacity is reported as renewable capacity. Gross electricity generation from waste incineration plants set at 50%.

2 Capacity of run-of-river and storage hydropower plants as well as pumped storage power plants with natural inflow. Gross electricity generation from pumped storage power plants only includes electricity generation from natural inflow.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3 and 4); provisional figures

Figure 8: Shares of total RE installed capacity and gross RE electricity generation in 2020, 2021 and 2022



1 Capacity of run-of-river and storage hydropower plants as well as pumped storage power plants with natural inflow. Gross electricity generation from pumped storage power plants only includes electricity generation from natural inflow.

2 incl. sewage sludge

3 Power of all waste incineration plants for renewable and non-renewable waste is taken into account. Here, 50% of the total waste incineration capacity is designated as renewable capacity. Gross electricity generation from waste incineration plants set at 50%.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 3 and 4); provisional figures

Heat

Renewable energy sources gain in importance for heat supply

Final energy consumption for heating and cooling from renewable energy sources rose by almost 6% to a new record of 211.7 terawatt-hours in 2022 (2021: 199.9 terawatt-hours). This is noteworthy as overall heat consumption was a good 8 % lower than in the previous year at 1,162 terawatt-hours (2021: 1,264 terawatt-hours) due to the milder weather and savings measures as a result of the Russian war of aggression against Ukraine. This shows that renewable energies have become more attractive during the energy crisis and have increasingly replaced fossil fuels, especially natural gas. Overall, the share of renewable energy in total final energy consumption for heating and cooling increased by 2.4 percentage points to 18.2% in 2022 (2021: 15.8%).

The trend for individual renewable energy sources in the heating sector was positive across the board in 2022. The most significant increases, however, were recorded in the use of geothermal energy and ambient heat as well as in the use of solar heat.

Slight rise in heat generation from biomass

By far the most important heat source among renewable energy sources was once again biomass, which still accounted for around 85% of the consumption of renewable energy for heating in 2022 (2021: 86%). Compared to the previous year, the consumption of biomass heat increased by just under 5% to 180.3 terawatt-hours (2021: 172.4 terawatt-hours) despite the significantly milder weather. The largest share of this was wood consumption in private households, which rose only slightly (plus 1.8%), while consumption in industry rose sharply (plus 36.8%). In contrast, wood consumption in the trade, commerce and services sector fell slightly (minus 6.4%).

The increase in private households is partly due to the significant rise in sales of pellet heating systems in 2022. According to industry figures, a total of 123,400 new pellet firing systems were installed, 43% more than in the previous year. Among new pellet systems, 63% were central heating systems and 37% were stoves. The total number of pellet firing systems rose to 680,000. As a result, pellet consumption increased by a good 10% to 3.2 million tonnes (2021: 2.9 million tonnes) [4].

Table 5: Final energy consumption for heating and cooling generation based on renewable energy sources in 2021 and 2022

	Renewable energy sources 2021		Renewable energy sources 2022	
	Final energy consumption heat and cooling (GWh)[9]	Share of final energy consumption for heating and cooling[10] (%)	Final energy consumption heat and cooling (GWh)[9]	Share of final energy consumption for heating and cooling[10] (%)
Biogenic solid fuels (households)[1, 3]	78,559	6.2	79,968	6.9
Biogenic solid fuels (TCS sector)[2]	21,821	1.7	20,414	1.8
Biogenic solid fuels (industry)[3]	24,820	2.0	33,946	2.9
Biogenic solid fuels (HP/CHP)[4]	6,796	0.5	6,346	0.5
Biogenic liquid fuels[5]	2,599	0.2	2,430	0.2
Biogas	14,818	1.2	15,152	1.3
Biomethane	4,982	0.4	4,769	0.4
Sewage gas	2,367	0.2	2,375	0.2
Landfill gas	85	0.01	81	0.01
Biogenic fraction of waste[6]	15,601	1.2	14,836	1.3
Solar thermal energy	8,551	0.7	9,733	0.8
Deep geothermal energy[7]	1,575	0.1	1,819	0.2
Near-surface geoth. Energy. ambient heat[8]	17,332	1.4	19,878	1.7
Total	**199,906**	**15.8**	**211,747**	**18.2**

1 Mostly wood, incl. wood pellets and charcoal

2 Including charcoal, TCS = trade, commerce, services sectors

3 Including sewage sludge

4 Including sewage sludge; HP = heating plants, CHP = combined heat and power plants

5 Including consumption of biodiesel in agriculture, forestry, construction and military

6 Estimated at 50% in waste incineration plants

7 Including balneological facilities

8 Renewable heat from heat pumps (air/water, water/water and brine/water heat pumps as well as hot water heat pumps and gas heat pumps)

9 1,000 GWh = 1 TWh

10 Relates to final energy consumption for space heating, hot water, process heat, air conditioning and process cooling, 2021: 1.263,9 TWh; 2022: 1.162,0 TWh ([3], Table 7)

For more details on the methodology for calculating the share and on correspondence to the EEG goal for the heating sector, see the 'Information on methodology' section in the appendix.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5); provisional figures

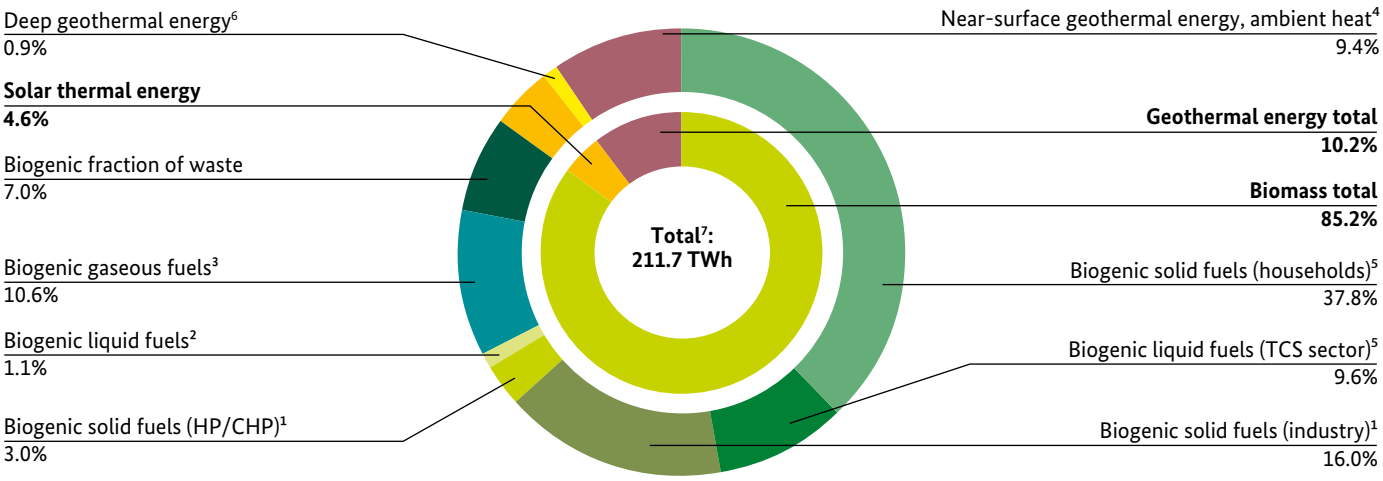
Record yield for solar heat

Demand for solar thermal energy has also picked up in the wake of the energy crisis. At 709,000 square metres, 12% more collector area was installed in 2022 than in the previous year. Overall, taking into account the dismantling or replacement of old systems, a good 22.4 million square metres of collector area were installed in Germany by the end of the year. As it did for photovoltaics, the sunny summer half-year also ensured record yields for solar thermal energy: at 9.7 terawatt-hours, 14% more solar heat was generated than in the previous year (2021: 8.6 terawatt-hours). Solar thermal energy thus contributed 4.6% of total final energy consumption for heating and cooling from renewable energies, an increase on the previous year (2021: 4.3%).

Heat pump market sustains strong growth

Even before heat pumps became the focus of the Building Energy Act debate, their importance in the heating market for 2022 had increased significantly. With around 236,000 heating heat pumps, 53% more systems utilising geothermal and ambient heat for heating buildings were installed than in the previous year (2021: 154,000 systems). Of these systems, 205,000 or 87% were air source heat pumps while the remaining 31,000 were ground source systems. Sales of heat pumps for domestic hot water heating almost doubled to 45,500 (2021: 23,500). A ramp-up of the heat pump market was quite evident. As a result, the total number of heat pumps in Germany increased by 18% to around 1.67 million systems in 2022. This was accompanied by a sharp rise in the contribution of geothermal energy and ambient heat towards heat consumption. Including deep geothermal and balneological plants (geothermal heat generation for pools), 21.7 terawatt-hours were generated in 2022, around 15% more than in the previous year (2021: 18.9 terawatt-hours). Geothermal energy and ambient heat thus accounted for 10.2% of total final energy consumption for heating and cooling from renewable energy sources (2021: 9.5%).

Figure 9: Final energy consumption for heat generation based on renewable energy sources, 2022



1 Including sewage sludge
2 Including consumption of biodiesel in agriculture, forestry, construction and military
3 Biogas, biomethane, sewage gas and landfill gas
4 Renewable heat from heat pumps (air/water, water/water and brine/water heat pumps as well as hot water heat pumps and gas heat pumps)
5 Including charcoal
6 Including balneological facilities
7 Including district heating

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5); provisional figures

Table 6: Final energy consumption for heat generation based on renewable energy sources

	Solid biomass[1]	Liquid biomass[2]	Gaseous biomass[3]	Solar thermal energy	Near-surface geothermal energy, ambient heat[4]	Total FEC heat[6]	RE share of FEC of heat[6]
	(GWh)[5]					(GWh)[5]	(%)
2005	92,425	1,225	3,188	2,857	3,372	**103,067**	**7.9**
2006	103,472	1,814	3,574	3,363	3,839	**116,062**	**8.6**
2007	110,874	2,869	6,026	3,746	4,513	**128,028**	**10.7**
2008	119,643	3,442	5,922	4,293	5,290	**138,590**	**10.6**
2009	114,779	3,735	7,680	5,061	6,151	**137,406**	**11.4**
2010	139,945	3,442	10,432	5,383	6,983	**166,185**	**12.4**
2011	129,611	2,603	12,272	6,160	7,862	**158,508**	**12.8**
2012	143,054	2,204	12,343	6,416	8,821	**172,838**	**13.7**
2013	147,414	2,196	13,889	6,500	9,722	**179,721**	**13.8**
2014	127,804	2,372	15,806	7,026	10,698	**163,706**	**13.8**
2015	129,486	2,189	17,679	7,562	11,370	**168,286**	**13.7**
2016	127,979	2,188	18,511	7,604	12,342	**168,624**	**13.7**
2017	131,031	2,194	18,968	7,834	13,284	**173,311**	**14.0**
2018	132,774	2,298	19,775	8,955	14,463	**178,265**	**14.8**
2019	135,586	2,383	20,275	8,667	15,612	**182,523**	**15.0**
2020	130,610	3,217	21,028	9,014	16,989	**180,858**	**15.1**
2021	147,597	2,599	22,252	8,551	18,907	**199,906**	**15.8**
2022	155,510	2,430	22,377	9,733	21,697	**211,747**	**18.2**

1 Including the biogenic share of waste (estimated at 50% in waste incineration plants), sewage sludge and charcoal.

2 Including consumption of biodiesel in agriculture, forestry, construction and military; including added bioethanol

3 Biogas, biomethane, sewage gas and landfill gas

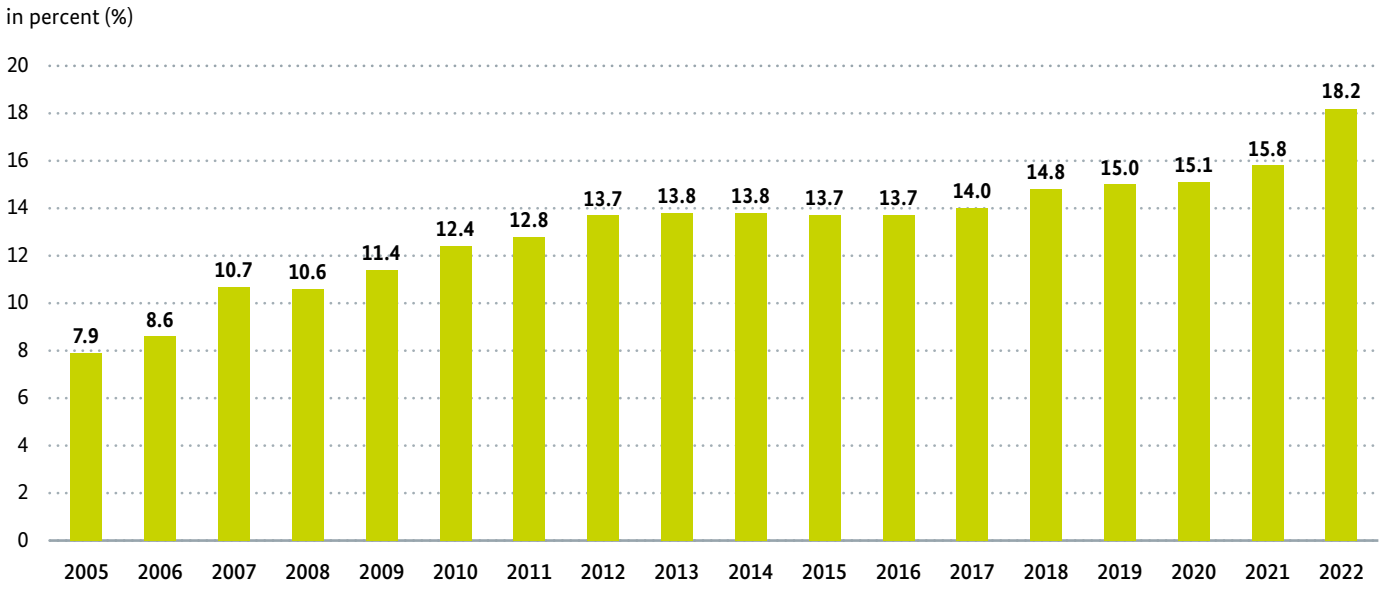
4 Including heat from deep geothermal energy and renewable heat from heat pumps (air/water, water/water and brine/water heat pumps as well as hot water heat pumps and gas heat pumps) and including balneological facilities

5 1,000 GWh = 1 TWh

6 Including district heating

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5); provisional figures

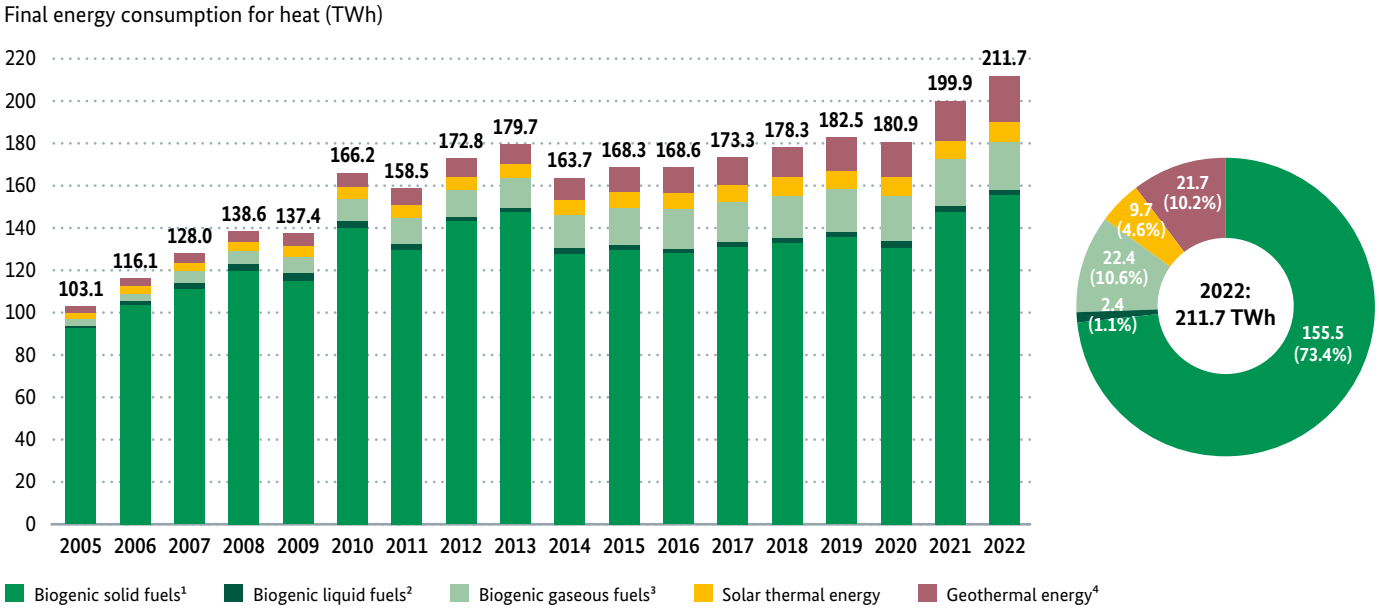
Figure 10: Share of renewables in final energy consumption for heat generation



According to the target set in the updated EU Renewable Energy Directive (RED II), the share of renewable energy sources in final energy consumption for heating and cooling should reach 49% by 2030.

Sources: Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany" ([3], Table 5); provisional figures

Figure 11: Development of final energy consumption for heating and cooling from renewable energy sources



Final energy consumption for heating and cooling from renewable energy sources for previous years see source [3].

1 Biogenic fraction of waste in waste incineration plants estimated at 50 %, since 2008 municipal waste only fuel input for heat production in decentralised CHP plants; including charcoal and sewage sludge

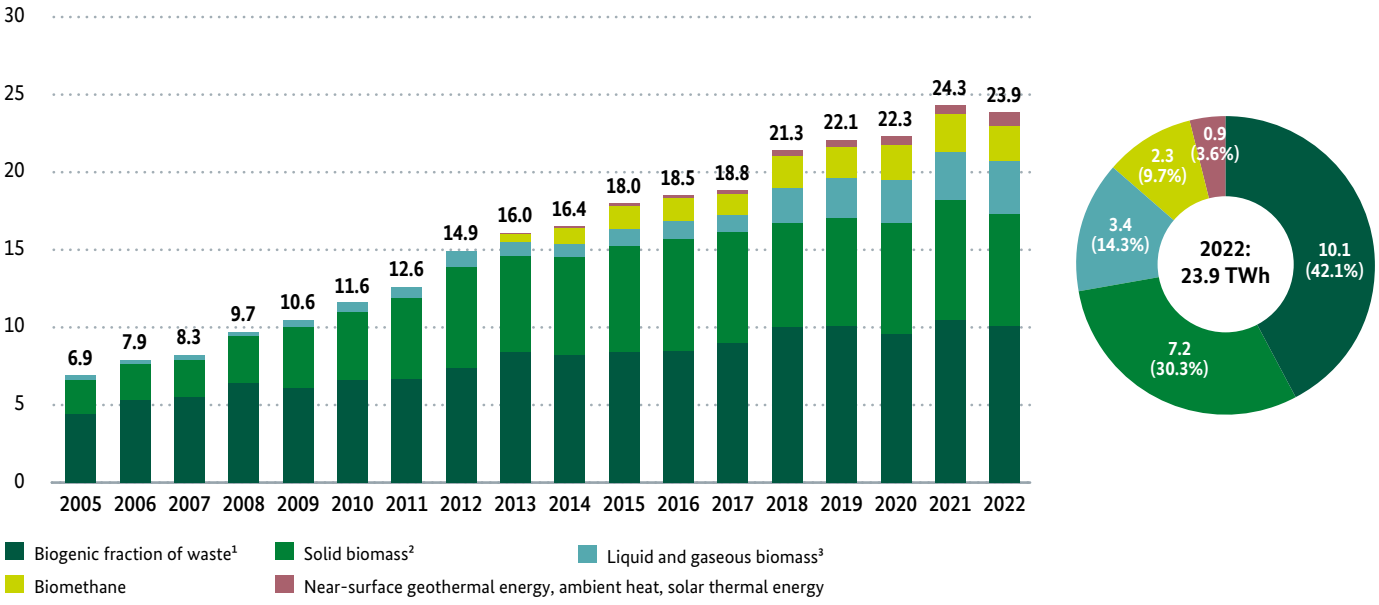
2 Including consumption of biodiesel in agriculture, forestry and military; since 2010 including blended bioethanol

3 Biogas, Biomethane, Landfill- and Sewage gas

4 Based on GZB, renewable heat from heat pumps (air-water, water-water, brine-water, process water and gas heat pumps)

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5); provisional figures

Figure 12: Development of final energy consumption for heating and cooling from renewable energy sources in district heating generation



Grid losses are not taken into account. Final energy consumption for heating and cooling from renewable energy sources in the household sector for previous years see Source [3].

1 Biogenic share of waste in waste incineration plants set at 50%, from 2008 only municipal waste

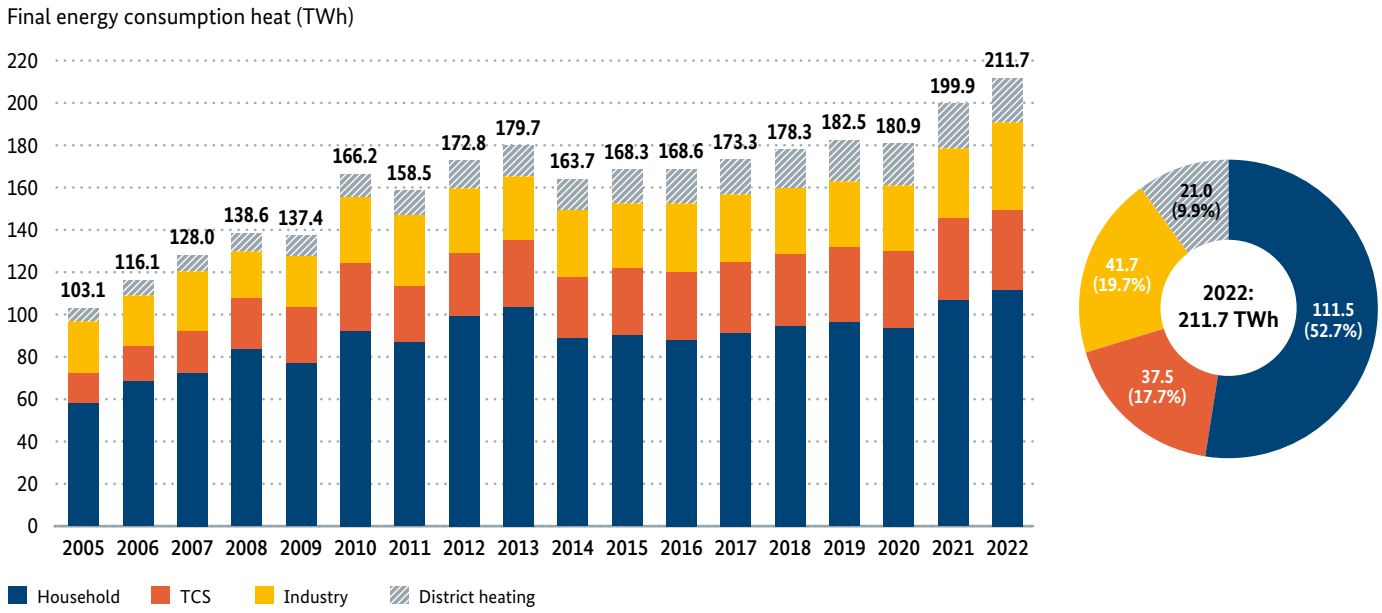
2 Including sewage sludge

3 Total gaseous fuels from biogas. Biomethane. Sewage gas. Landfill gas and biogenic liquid fuel; until 2012 incl. geothermal energy. Ambient heat. Solar thermal energy and biomethane; from 2013 shown separately

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5.1); provisional figures

The following figures show the final energy consumption of renewable energy sources for heating and cooling in the sectors households, TCS (trade, services and commerce) and industry.

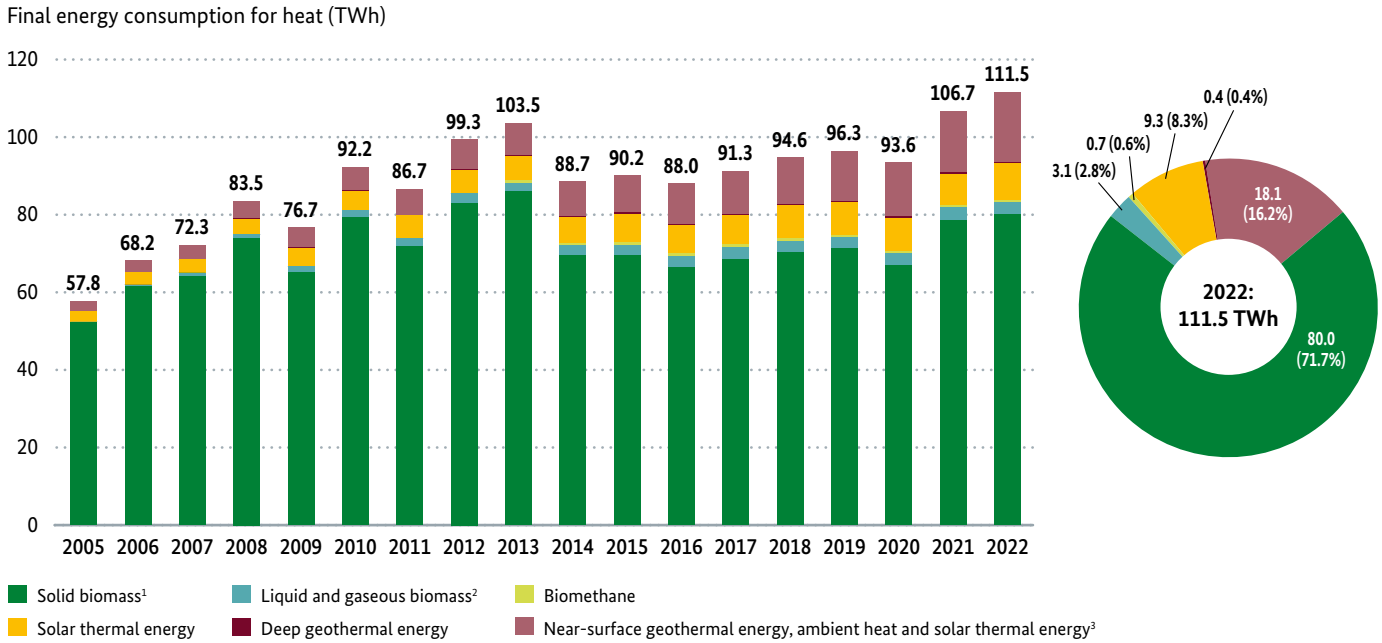
Figure 13: Development of final energy consumption for heating and cooling from renewable energy sources by final energy sector



Final energy consumption for heating and cooling from renewable energy sources in the household sector for previous years see Source [3]. In the case of district heating, no direct allocation by application sector is possible.

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5.2); provisional figures

Figure 14: Development of final energy consumption for heating and cooling from renewable energy sources in the household sector



Final energy consumption for heating and cooling from renewable energy sources in the household sector in previous years see source [3].

1 Including sewage sludge

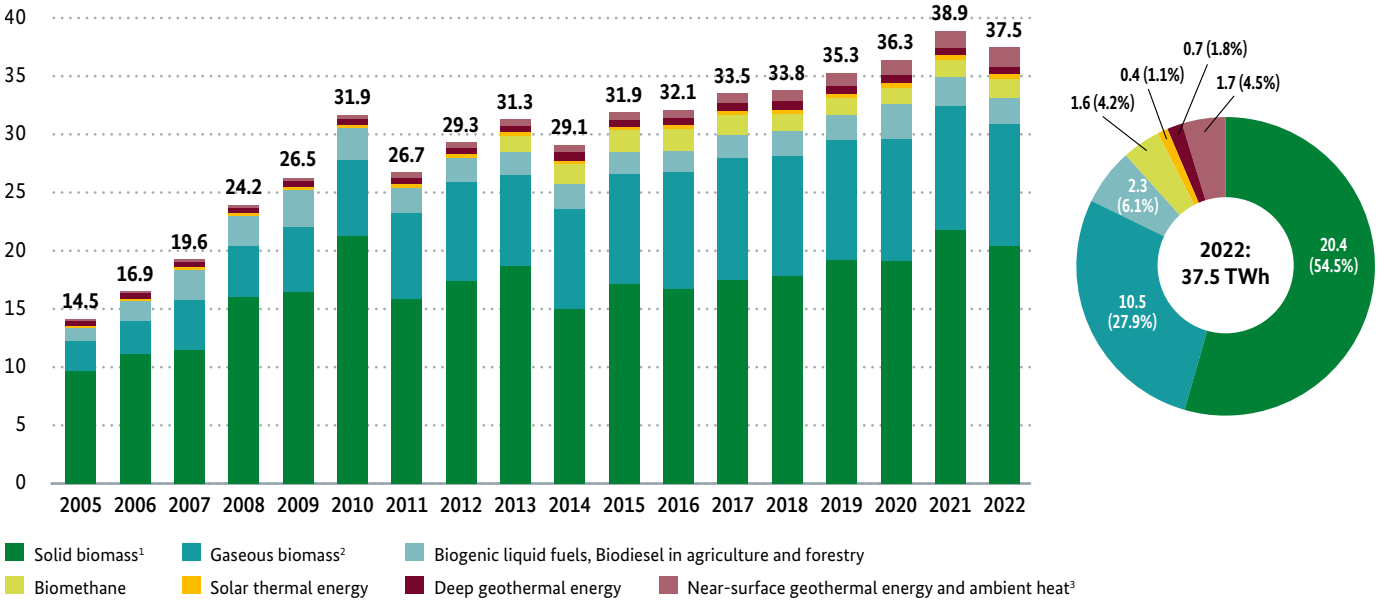
2 Total gaseous fuels from biogas. Sewage gas, landfill gas and biogenic liquid fuel; biomethane since 2013 depicted separately

3 Based on GZB, renewable heat from heat pumps (air-water, water-water, brine-water, process water and gas heat pumps)

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5.2); provisional figures

Figure 15: Development of final energy consumption for heating and cooling from renewable energy sources in the TCS sector

Final energy consumption for heat (TWh)[4]



2022 provisional data. Final energy consumption for heating and cooling from renewable energy sources in the TCS sector in previous years see Source [3].

1 Including sewage sludge

2 Sum of biogas, biomethane, sewage gas and landfill gas; biomethane since 2013 depicted separately

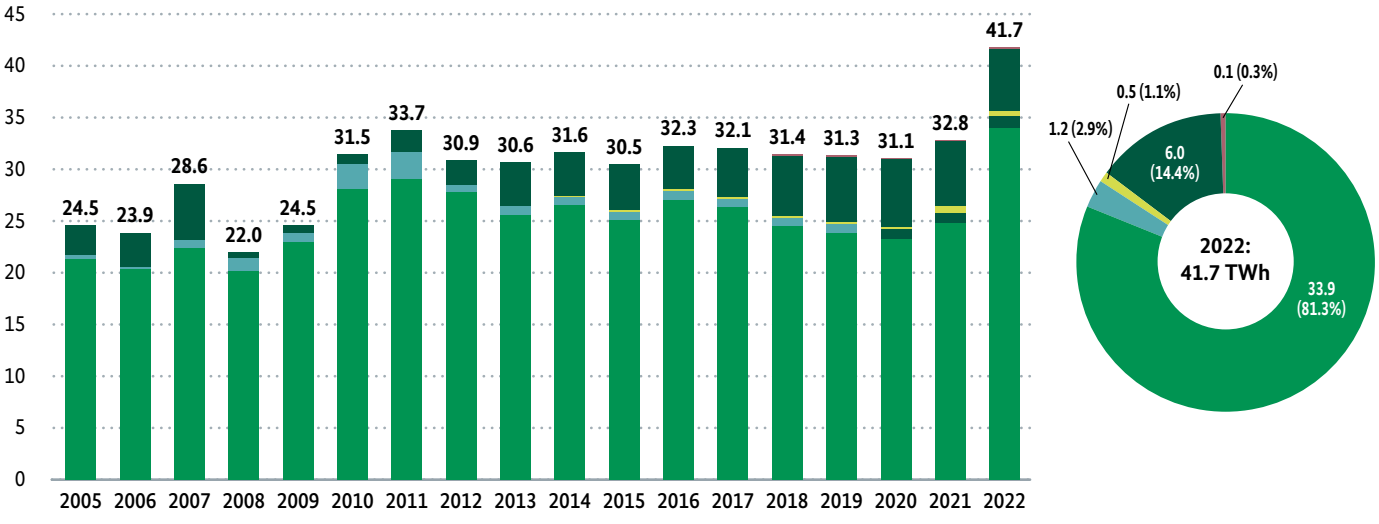
3 Based on GZB, renewable heat from heat pumps (air/water, water/water, brine/water, process water and gas heat pumps)

4 Before 2012, contained small amounts of energy from biogenic waste in the GHD sector

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5.2); provisional figures

Figure 16: Development of final energy consumption for heating and cooling from renewable energy sources in the industrial sector

Final energy consumption for heat (TWh)



Final energy consumption for heating and cooling from renewable energy sources in the industrial sector in previous years see Source [3]

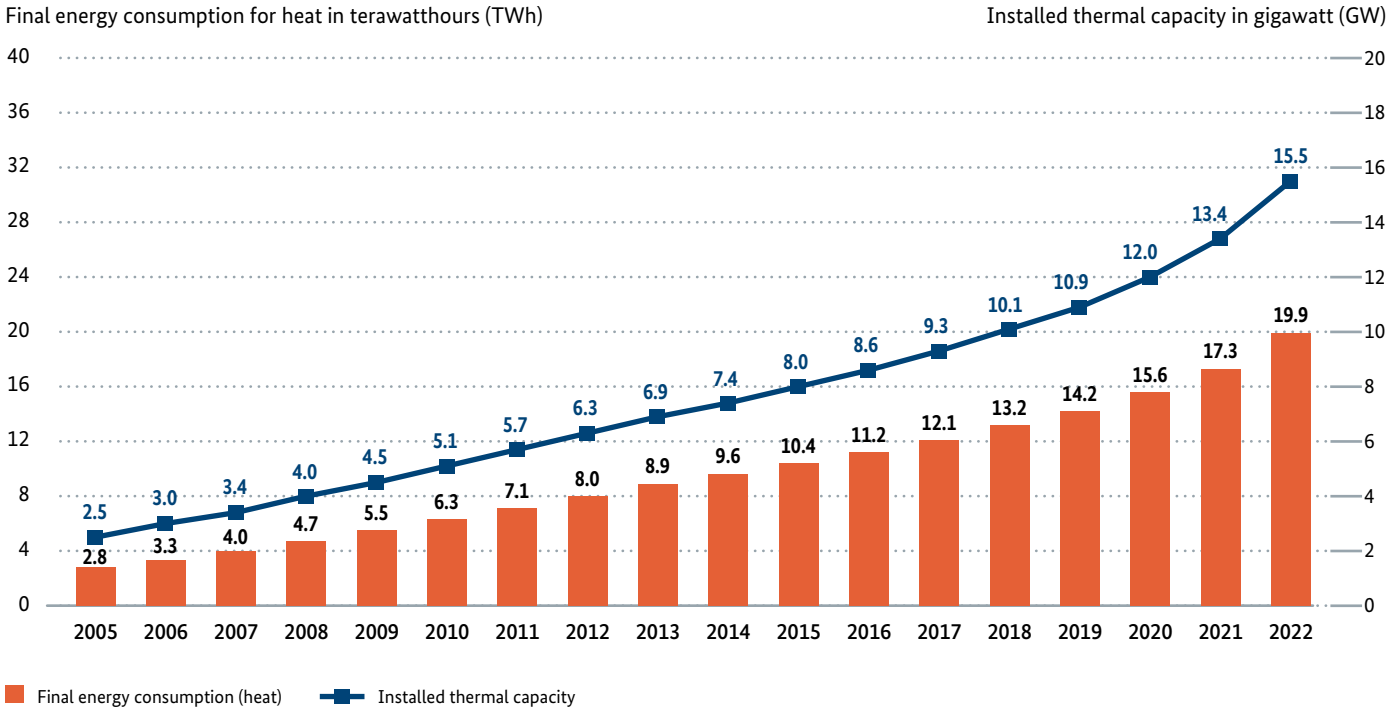
1 Including sewage sludge

2 Sum of gaseous and liquid biomasses: biogas, biomethane, sewage gas, landfill gas and liquid biofuels; since 2013 biomethane depicted separately

3 Biogenic share of waste in waste incineration plants set at 50%. From 2008 only municipal waste

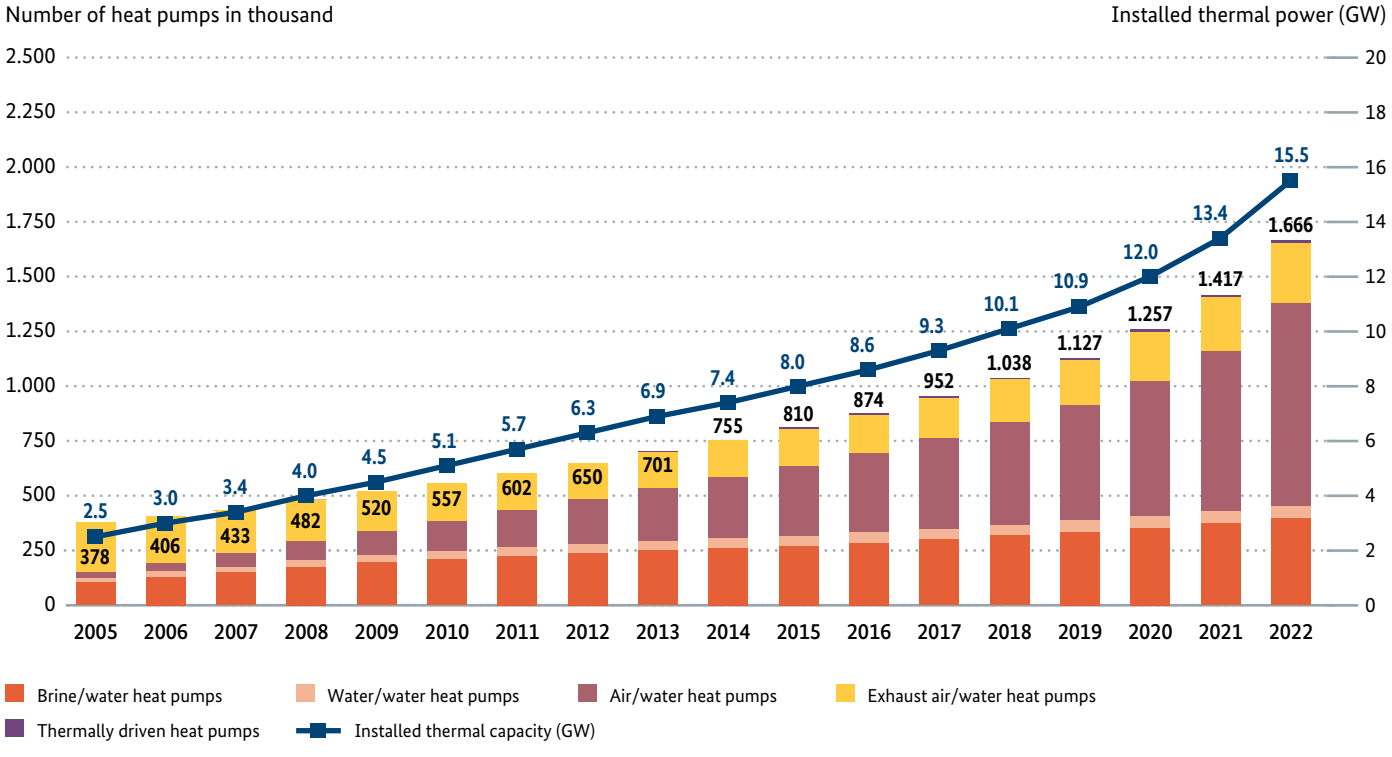
Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 5.2); provisional figures

Figure 17: Development of final energy consumption from near-surface geothermal energy and ambient heat for heating and cooling and thermal capacity of heat pumps in Germany



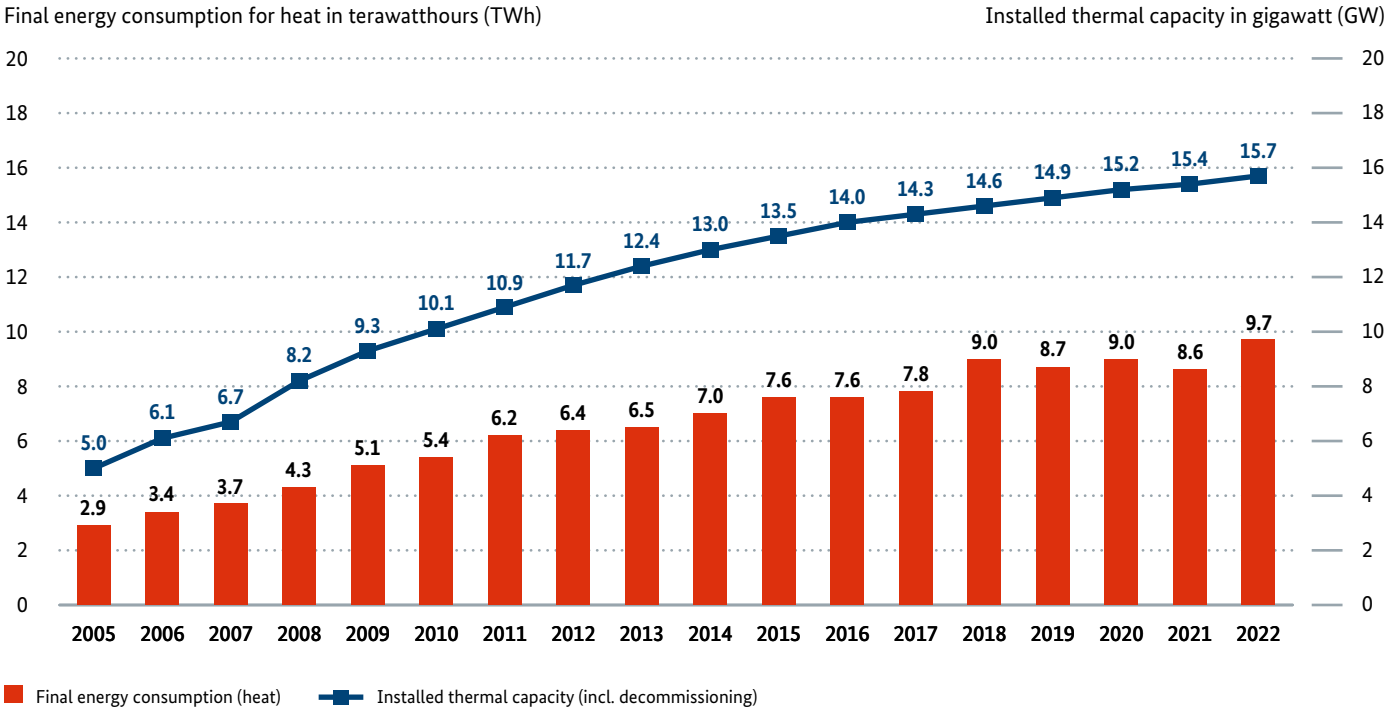
Sources: BMWK based on data from AGEE-Stat

Figure 18: Development of heat pumps in Germany



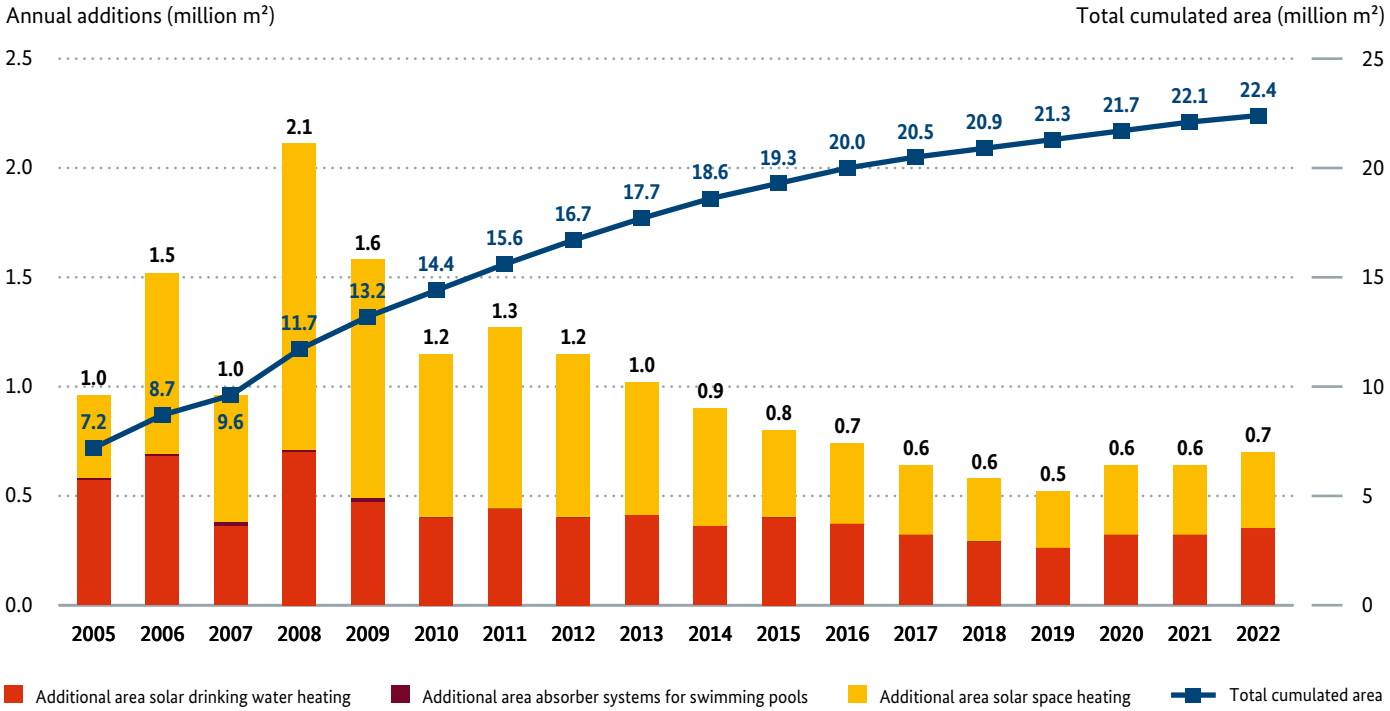
Sources: BMWK based on data from AGEE-Stat

Figure 19: Development of final energy consumption from solar thermal energy for heating and cooling and thermal plant capacity in Germany



Sources: BMWK based on data from AGEE-Stat

Figure 20: Additions and existing area of solar thermal plants in Germany



This includes combined solar thermal systems, solar thermal domestic hot water heating and central heating backup, as well as the dismantling of old systems in all categories

Sources: BMWK based on data from AGEE-Stat

Table 7: Solar-based heat: area and heat generation capacity of solar collectors in Germany

	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
Cumulative area (1,000 m²)	7,157	14,376	19,304	19,964	20,484	20,917	21,255	21,686	22,057	22,415
Cumulative output (MW)	5,010	10,063	13,513	13,975	14,339	14,642	14,879	15,180	15,440	15,690

Figures take account of old installations taken out of service.

Sources: BMWK based on data from AGEE-Stat

Transport

Biofuel sales stabilise

After a significant decline during the previous year, sales of biofuels stabilised at the prior-year level of 6.63 million tonnes in 2022 (2021: 6.59 million tonnes). Biofuel types again showed a somewhat varied picture: at 2.37 million tonnes, slightly less biodiesel and so-called HVO ("Hydrotreated Vegetable Oils") were sold than in the previous year (2021: 2.38 million tonnes) while sales of bioethanol rose by 3.3% to 1.18 million tonnes (2021: 1.14 million tonnes). The use of biomethane in transport increased to 1,061 gigawatt hours (2021: 965 gigawatt hours). In total, biofuels increased slightly to 0.4% of energy content compared to the previous year.

Electric vehicles advance

In 2022, the use of electricity from renewable energy continued to increase significantly within transport. This is partly due to a larger share of the electricity mix, but also to the further significant rise in the number of new registrations of electrically powered vehicles. In 2022, around 833,000 cars with electric drive systems (battery-electric or plug-in hybrid) were newly registered for 22% more than in the previous year (2021: 681,000). Among the newly registered cars, 471,000 had a purely battery-electric drive (up 32%/2021: 356,000), which was almost 18% of total new registrations. Overall, the consumption of electricity from renewable energy sources in the transport sector increased in 2022 by almost 15% year-on-year to 6.1 terawatt-hours (2021: 5.3 terawatt-hours). Although the majority of this was still accounted for by rail transport, the share from road transport grew steadily from 10.8% in 2021 to 18.4 % in 2022.

Biofuels and electricity from renewable energy sources together contributed 40.7 terawatt-hours to energy consumption in the transport sector in 2022, or 2.3% more than in the previous year (2021: 39.8 terawatt-hours). As total final energy consumption in the transport sector also increased by 1.8% year-on-year to 593.9 terawatt-hours (2021: 583.3 terawatt-hours), the share of renewable energy sources in final energy consumption in the transport sector was only slightly higher than in the previous year at 6.9% (2021: 6.8%).

Table 8: Consumption of renewable energy sources in the transport sector in 2021 and 2022

	Renewable energy sources 2021		Renewable energy sources 2022	
	Final energy consumption of transport (GWh)[3]	Share of FEC of transport[4] (%)	Final energy consumption of transport (GWh)[3]	Share of FEC of transport[4] (%)
Biodiesel[1]	25,072	4.3	24,849	4.2
Vegetable oil	21	0.004	21	0.004
Bioethanol	8,412	1.4	8,692	1.5
Biomethane	965	0.2	1,061	0.2
RE electricity consumption in transport[2]	5,340	0.9	6,121	1.0
Total	**39,810**	**6.8**	**40,744**	**6.9**

1 Consumption of biodiesel (incl. HVO) in the transport sector, excluding use in agriculture, forestry, construction and military

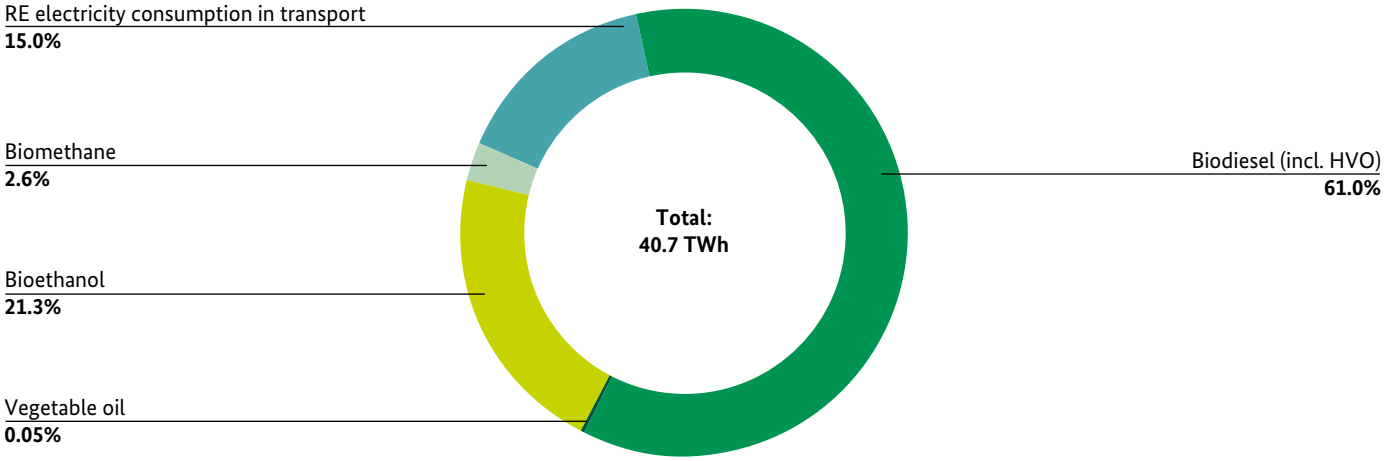
2 Calculated from total electricity consumption in the transport sector according to AGEB [5] and the share of renewable energy in gross electricity consumption according to AGEE-Stat (see table 3)

3 1,000 GWh = 1 TWh

4 Based on final energy consumption in transport in 2021: 583.3 TWh; 2022: 593.9 TWh according to AGEB [5] and AGEE-Stat, without energy consumption for international air traffic

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 6); provisional figures

Figure 21: Consumption of renewable energy sources in the transport sector, 2022



Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 6); provisional figures

Table 9: Consumption of renewable energy sources in the transport sector

	Biodiesel[1]	Vegetable oil	Bioethanol	Biomethane	RE electricity consumption[2]	Final energy consumption of transport	Share of FEC of transport
	(GWh)[3]					(GWh)[3]	(%)
2005	17,666	1,828	1,780	0	1,353	**22,627**	**3.7**
2006	27,938	7,206	3,828	0	1,484	**40,456**	**6.2**
2007	32,282	8,533	3,391	0	1,763	**45,969**	**7.4**
2008	25,873	4,042	4,608	4	1,699	**36,226**	**5.7**
2009	22,966	961	6,576	13	1,925	**32,441**	**5.3**
2010	24,359	574	8,537	75	2,078	**35,623**	**5.9**
2011	23,556	188	9,031	92	2,494	**35,361**	**5.8**
2012	24,628	251	9,149	333	2,862	**37,223**	**6.1**
2013	21,945	0	8,832	483	3,017	**34,277**	**5.5**
2014	22,676	52	9,002	449	3,169	**35,348**	**5.7**
2015	20,829	10	8,589	345	3,523	**33,296**	**5.2**
2016	20,896	31	8,604	379	3,733	**33,643**	**5.2**
2017	21,354	31	8,464	445	4,328	**34,622**	**5.3**
2018	22,329	10	8,685	389	4,581	**35,994**	**5.5**
2019	22,109	21	8,353	660	4,897	**36,040**	**5.5**
2020	30,170	21	8,014	884	5,248	**44,337**	**7.5**
2021	25,072	21	8,412	965	5,340	**39,810**	**6.8**
2022	24,849	21	8,692	1,061	6,121	**40,744**	**6.9**

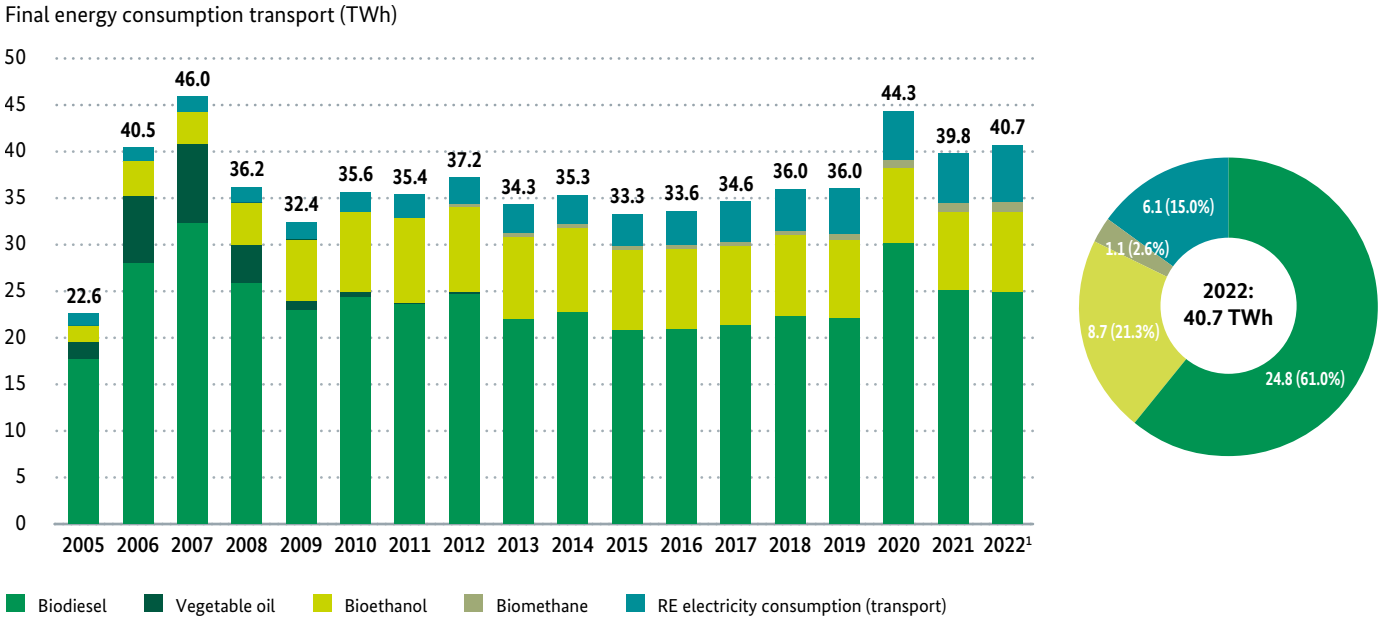
1 Consumption of biodiesel (incl. HVO) in the transport sector, excluding use in agriculture, forestry, construction and military

2 Calculated from total electricity consumption in the transport sector according to AGEB [5] and the share of renewable energy in gross electricity consumption for the particular year according to AGEE-Stat (see table 3)

3 1,000 GWh = 1 TWh

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 6); provisional figures

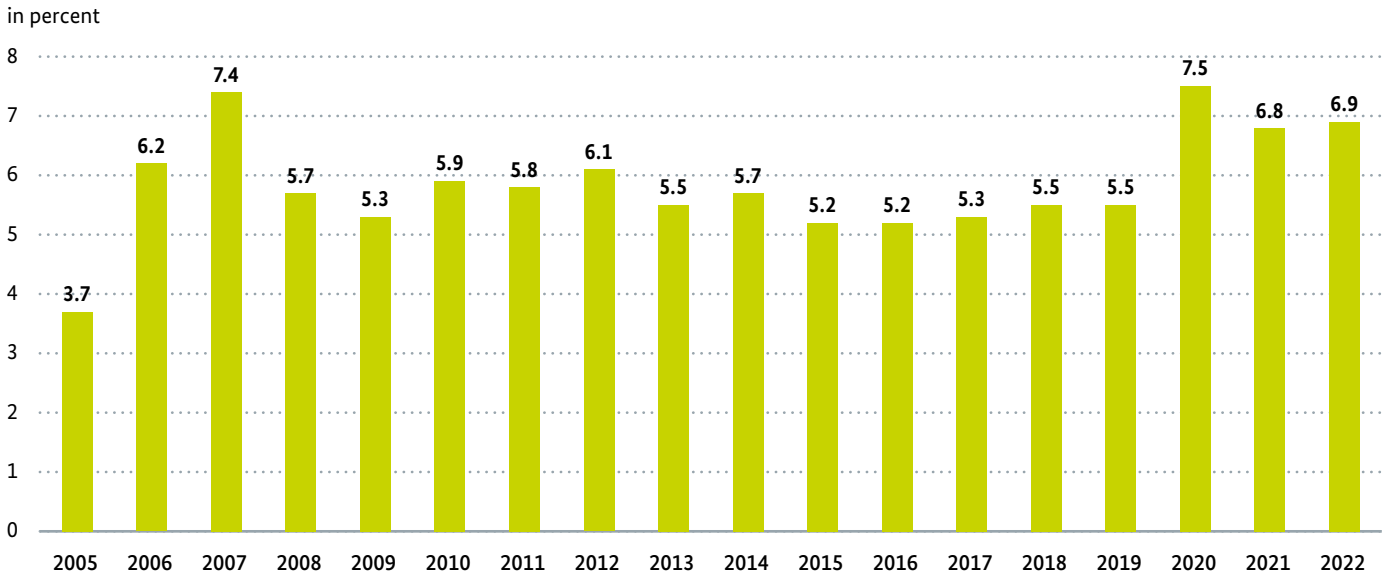
Figure 22: Consumption of renewable energy sources in the transport sector



1 Final energy consumption of the respective technologies for transport in previous years see table 9

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 6); provisional figures

Figure 23: Share of renewable energy in final energy consumption in the transport sector



However, the values given in Table 9 deviate from the calculation methodology of the EU Directive and include neither double counting nor a differing reference value for total final energy consumption. Further information on the calculation is available in the information on methodology section of this publication.

Sources: Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany" ([3], Table 6); provisional figures

Table 10: Consumption of renewables-based fuels in the transport sector

	2000	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
						(1,000 tons)					
Biodiesel[1]	250	1,720	2,361	1,998	2,005	2,073	2,169	2,145	2,805	2,378	2,368
Vegetable oil	16	175	55	1	3	3	1	2	2	2	2
Bioethanol	0	238	1,158	1,165	1,167	1,148	1,178	1,133	1,087	1,141	1,179
Biomethane[2]	0	0	6	25	28	33	29	49	65	71	78
Total	**266**	**2,133**	**3,580**	**3,189**	**3,203**	**3,257**	**3,377**	**3,329**	**3,959**	**3,592**	**3,627**

1 Consumption of biodiesel (incl. HVO) in the transport sector, excluding use in agriculture, forestry, construction and military

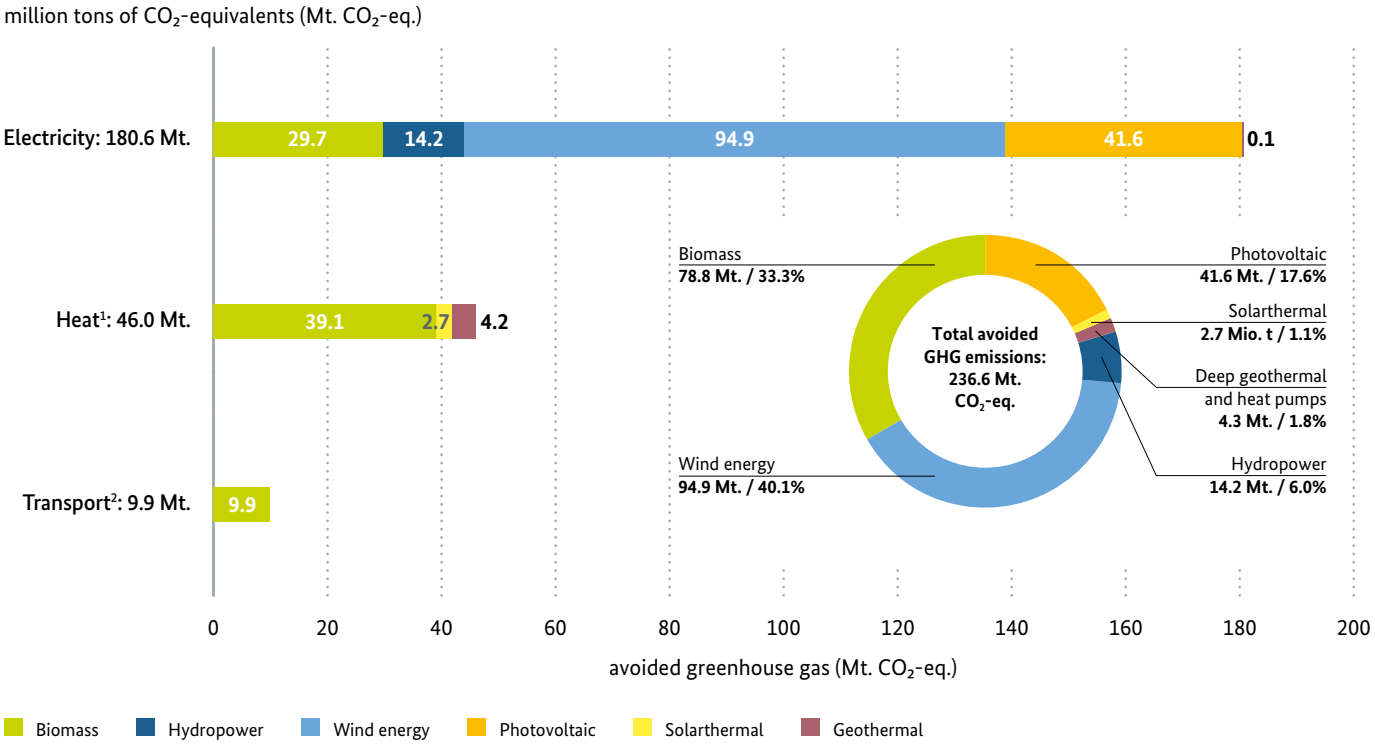
2 Calculated using a calorific value of 48.865 MJ/kg

Sources: BMWK based on data from AGEE-Stat "Time series for the development of renewable energy sources in Germany", ([3], Table 6); provisional figures

Emissions prevented through the use of renewable energy

The expansion of renewable energy contributes significantly to achieving climate protection goals. In 2022, greenhouse gas emissions totalling almost 237 million tonnes of CO_2-equivalents were avoided. Most of the greenhouse gas emissions were once again prevented through electricity generation from wind turbines (95 million tonnes of CO_2-equivalents). The entire electricity sector accounted for over 181 million tonnes. Around 46 million tonnes fewer CO_2-equivalents were emitted in the heating sector and around ten million tonnes fewer through the use of biofuels in transport (see Figure 24).

Figure 24: Net balance of greenhouse gas emissions avoided through the use of renewable energy, 2022



1 Does not include charcoal consumption

2 Exclusively biogenic fuels in the transport sector (excluding agriculture, forestry, construction and the military and excluding electricity consumption by the transport sector), based on provisional data from the Federal Office for Agriculture and Food (BLE) for 2021 and the fossil baseline values pursuant to § 3 and § 10 of the 38th Federal Immission Control Ordinance (BImSchV)

Sources: German Environment Agency [6] – based on the sources quoted herein, provisional figures

The calculations of the emissions savings arising from the use of renewable energy are based on net figures[2]. The volume of emissions created by the use of renewable energy sources (final energy supply) are offset against the gross emissions avoided by the substitution of fossil energy sources. Most upstream process chains involved in the production and supply of the various energy sources as well as for the plant construction and operation are also taken into account.

In the electricity and heating sectors, technology-specific substitution factors were used. The underlying model for the electricity sector gives special consideration to the increasing interconnectedness of the European electricity market. The substitution factors are determined by comparing the real development of the European electricity generation sector with a plausible development path, disregarding the German expansion of renewable energy. In the heating sector, on the other hand, the substitution effect among the application areas private households, the TCS sector and industry as well as general supply can differ significantly. The substitution factors were therefore determined separately for each energy source and area of use. In addition, the different efficiencies of renewable and conventional heating systems were considered in the balancing.

The emissions balance for the use of biomass depends on the type and origin of the raw materials. The life cycle was also modelled to ascertain the environmental footprint for the purpose of balancing [6]. If the raw materials are not biogenic materials or waste, land use changes resulting from the cultivation of energy crops must be considered. However, it is difficult to quantify indirect land use changes. Therefore, these changes have not yet been taken into account in emissions accounting. Various model-based calculations conclude that indirect land-use changes can lead to significant greenhouse gas emissions, which can partially or completely offset the greenhouse gas emission savings of individual biofuels.

The emissions calculation of biofuels[3] is based on the greenhouse gas emissions (including the raw material basis) accounted for or applied in the course of the GHG quota itself, as published by the Federal Agency for Agriculture and Food (BLE) in its annual evaluation and experience report on the Biofuels/Biomass Electricity Sustainability Ordinance [23] as well as the fossil base values of the 38th BImSchV (Regulation Implementing the Federal Immission Control Act) according to §3 and §10.

The emissions of individual greenhouse gases and air pollutants resulting from the use of biofuels were roughly derived by the German Environment Agency (UBA) based on total GHG emissions.

Table 11 contains the results for the balanced greenhouse gases and air pollutants. The greenhouse gas avoidance is particularly high for electricity generation. This can be explained, among other reasons, by the low emissions from the production and operation of the renewable technologies used compared to emission-increasing fossil power generation. Negative balance values again occur for the precursor substances for ground-level ozone. This is mainly due to the use of biogas. In the heating sector, emissions of some air pollutants increase due to the combustion of wood, particularly in older tiled stoves and fireplaces. However, these must be successively decommissioned or replaced due to legal regulations. Of particular importance are the negative balances for carbon monoxide and volatile organic compounds as well as dust emissions of all particle sizes. The use of biofuels in transport also results in increased nitrous oxide and methane emissions from the cultivation of energy crops.

2 Detailed documentation of the methodological principles of emissions accounting for renewable energy can be found in the UBA publication “Emissionsbilanz erneuerbarer Energieträger – Bestimmung der vermiedenen Emissionen 2022” (Emissions balance of renewable energy sources – determination of avoided emissions 2022) (in German only) [6].

3 Overall, it can be estimated that the emission reductions from biofuel use are somewhat overstated. The reasons for this are the use of the official, regional NUTS2 values for biomass cultivation according to RED and the official specifications used for the substitution of fossil CO_2 with biogenic CO_2 produced during bioethanol production.

Table 11: Net emissions balance for renewable energy sources used in electricity, heat and transport, 2022

		Renewables-based electricity generation total: 254,185 GWh		Renewables-based heat consumption total: 211,747 GWh[5]		Renewables-based consumption for transport total: 40,744 GWh[6, 7]		Total
Greenhouse gas/ Air pollutant		Avoidance factor	Avoided emissions	Avoidance factor	Avoided emissions	Avoidance factor	Avoided emissions	Avoided emissions
		(g/kWh)	(1,000 t)	(g/kWh)	(1,000 t)	(g/kWh)	(1,000 t)	(1,000 t)
Greenhouse effect[1]	CO_2	697	177,140	223	46,947	307	10,613	234,700
	CH_4	0.66	167.5	-0.04	-9.29	-0.16	-5.49	153
	N_2O	-0.02	-4.5	-0.01	-2.6	-0.06	-1.96	-9
	CO_2-equivalent	711	180,647	218	46,000	287	9,939	236,586
Acidification[2]	SO_2	0.21	54	0.02	4.9	-0.15	-5.06	54
	NO_X	0.44	112.2	-0.17	-36.5	0.4	13.98	90
	SO_2-equivalent	0.52	131	-0.1	-20.5	0.13	4.64	115
Ozone[3] Particles[4]	CO	-0.35	-88.1	-1.98	-416.9	1.03	35.74	-469
	NMVOC	0.03	6.7	-0.17	-36.1	0.19	6.71	-23
	Dust	0.004	1.1	-0.1	-20.0	-0.02	-0.61	-20

1 Other greenhouse gases (SF_6, CFCs, HCFCs) are not included.

2 Other air pollutants with acidification potential (NH_3, HCl, HF) are not included.

3 NMVOC and CO are important precursors for ground-level ozone, which contributes significantly to 'summer smog'.

4 Here, dust comprises the total emissions of suspended particulate matter of all particle sizes.

5 Does not include charcoal consumption

6 Does not include the consumption of biodiesel (incl. HVO) in agriculture, forestry, construction and the military and electricity consumption in the transport sector

7 Based on preliminary data from the Federal Office for Agriculture and Food

Source: German Environment Agency (UBA) [6] based on the sources quoted therein

Saving fossil fuels through the use of renewable energy sources

Table 12 and table 13 show the savings of fossil energy sources through the use of renewable energy in the areas of electricity, heat and transport in 2022 as well as in the period from 2010 to 2022. Total savings have risen continuously in recent years. Since fossil energy sources, i.e. mineral oil, natural gas and hard coal are largely imported, these savings also lead to a reduction in German energy imports.

Table 12: Savings in primary energy through the use of renewable energy sources, 2022

	Lignite	Hard coal	Natural gas	Divided into mineral oil:			Total
				Fuel oil	Diesel fuel	Gasolines	
	Primary energy (TWh)						
Electricity	78.8	385.7	111.2				**575.7**
Heat	15.8	18.3	98.6	69.7	1.8		**204.2**
Transport			1.1		20.1	9.9	**31.0**
Total	**94.7**	**404.0**	**210.9**	**69.7**	**21.9**	**9.9**	**810.9**
	Primary energy (PJ)						
Total	**340.7**	**1,454.2**	**759.1**	**251.0**	**78.7**	**35.5**	**2,919.4**
which corresponds to[1]	37.2	52.4	21,577	7,064	2,216	1,091	
	million t[2]	million t[3]	million m³	million litres	million litres	million litres	

The savings in fossil fuel are calculated using the same methodology as is used to calculate emissions balances, see UBA [6].

1 Savings in primary energy were calculated using the net calorific values determined by AGEB [7].

2 Including approximately 37.04 million tonnes of lignite, less than 0.01 million tonnes of lignite briquettes and approximately 0.13 million tonnes of pulverised coal

3 Including approx. 52.36 million tonnes of hard coal and approx. 0.05 million tonnes of coke from hard coal

Source: German Environment Agency (UBA) [6] based on the sources quoted therein

Table 13: Fossil fuel savings resulting from the use of renewables

	Electricity	Heat	Transport	Total
	Primary energy (TWh)			
2010	232.4	121.4	17.8	**371.6**
2011	275.1	118.4	18.6	**412.1**
2012	305.4	126.7	22.0	**454.1**
2013	323.5	131.0	20.9	**475.4**
2014	357.1	123.4	21.4	**501.9**
2015	431.8	152.6	20.0	**604.5**
2016	429.8	154.2	24.5	**608.5**
2017	479.4	161.3	27.0	**667.7**
2018	496.0	165.3	27.8	**689.2**
2019	555.4	168.8	26.4	**750.6**
2020	574.1	169.5	35.6	**779.2**
2021	538.1	188.5	30.8	**757.3**
2022	575.7	204.2	31.0	**810.9**

Source: German Environment Agency (UBA) [6] based on the sources quoted therein

The Renewable Energy Sources Act (RES)

The central pillar of the energy transition is electricity generation from renewable sources, which makes a significant contribution towards the realisation of climate targets. The current amendment to the Renewable Energy Sources Act (RES) 2023 has for the first time consistently aligned the Act with the achievement of the 1.5-degree target to which the EU, including Germany, committed itself under the Paris Agreement.

At the same time, the expansion of renewable energy is aimed at reducing dependence on fossil fuel imports since energy sovereignty has become a question of national and European security. Therefore, at least 80% of the electricity consumed in Germany should be generated from renewable energy sources by 2030. Once the coal phase-out has been completed, the next goal will be greenhouse gas neutrality of the electricity supply in Germany.

In Germany, the RES has been the central basis for the expansion of renewable energy in the electricity sector for more than two decades. Since its introduction in 2000, the law has been continuously developed. The latest amendment, the RES 2023, is part of one of the largest energy policy legislative packages and significantly improves the framework conditions for renewable energy. As part of this legislative package, other laws and ordinances were amended, including the Offshore Wind Energy Act (WindSeeG), Energy Industry Act (EnWG) and Combined Heat and Power Act (KWKG). This is intended to broadly accelerate the expansion of renewable energy.

The RES 2023 firmly anchors the goal of transformation to a sustainable and greenhouse gas-neutral electricity supply primarily based on renewable energy. The agreed upon increase in the share of electricity from renewable energy sources in gross electricity consumption to at least 80% by 2030 means that the renewables share of total electricity consumption (2022: 46.0%) should almost double within less than a decade. In absolute terms, the task is even greater due to rising electricity consumption, resulting in part from the advancing electrification of industrial processes, heat supply and transport. Up to 600 terawatt-hours of electricity should be generated annually from renewable energy by 2030, compared to around 254 terawatt-hours in 2022.

The basic principle that renewable energy serves the overriding public interest and public safety was introduced to accelerate the expansion of renewable energy and reach the targets. It takes precedence over other interests when future decisions are made. A significant increase in the speed of planning and authorisation procedures may result. Furthermore, the RES 2023 defines expansion options and tendering volumes for the individual technologies and increases them significantly compared to the RES 2021. Future growth will be based primarily on the use of solar and wind energy. For onshore wind energy, an annual average expansion rate of 10 gigawatts (including the dismantling of old plants to be compensated for) from 2025 onwards should ensure that a total of around 115 gigawatts of wind energy capacity is installed in Germany by 2030. In the area of photovoltaics, a total installed capacity of 215 gigawatts is foreseen for 2030.

Table 14: Status quo and expansion paths of onshore wind and solar energy according to RES 2023

	2022 Status quo	2024	2026	2028	2030	2035	2040
	Installed power (GW)						
Expansion path for onshore wind energy	58	69	84	99	115	157	160
Expansion path Photovoltaic	67	88	128	172	215	309	400

Sources: Renewable Energy Sources Act (RES) 2023 [8]

Other laws, such as the Wind Energy Area Requirements Act, have been enacted to break down significant barriers to onshore wind energy. The central aim is to make a total of 2% of Germany's land area available for wind energy by the end of 2032. Targets adjusted to particular circumstances were allocated to the individual Länder [9]. The RES 2023 also contains important improvements for the expansion of wind energy. For example, the number of auction dates has been increased, expansion has been strengthened for locations with less wind, and the degression of the maximum remuneration has been suspended for two years.

In the field of photovoltaics, framework conditions for rooftop and ground-mounted systems have been significantly improved by several individual measures. For example, location categories for ground-mounted systems were expanded. In addition to the previous categories such as conversion areas, verges and expanded disadvantaged areas, Agri-PV, Floating-PV and Moor-PV[4] were added. In order to accelerate the expansion of rooftop PV systems outside of tenders (installed system capacity < 1 MWp), the remuneration for all new systems was increased as of 30.07.2022. In addition, the degression of the statutory remuneration rates will be suspended until 2024 and then switched from monthly to half-yearly degression. As an incentive for the full use of roof surfaces, an increased remuneration was introduced for installations that feed all electricity generated into the grid (see details below). In cases of self-consumption, systems with full and partial feed-ins can be combined by tracking the electricity generated via different meters.

Another change for wind and photovoltaic projects is that citizens' energy companies will be removed from the tendering process. As a result, their projects can be realized faster and more predictably, i.e. without having to participate in tenders and without the risk of a surcharge. However, EU Commission regulations limit the size of such projects to a maximum of 18 megawatts for wind and 6 megawatts for photovoltaics. Regulations on the financial participation of municipalities in wind and solar projects have also been further developed. In particular, plants for other direct marketing as well as existing plants can benefit from this in the future.

In subsidising biomass, the focus is on highly flexible peak load power plants. This is intended to capitalise on the strengths of Biomass as a storable energy source to increase its value for the security of the power supply. Biomass plants totalling 8.4 gigawatts capacity should be installed by 2030 while subsidised tenders will be gradually reduced as of 2024. Tenders for biomethane were set to increase to 600 megawatts per year as of 2023. In the future, biomethane will only be used in highly flexible power plants. All new biomethane and combined heat and power plants (CHP plants) should also be ready for the ramp-up of a green hydrogen economy ('H2-ready'). The latter measure was regulated by an accompanying amendment to the Combined Heat and Power Act (KWKG 2023).

Innovation tenders will be continued for the further integration of renewable energy sources. These are special tenders for creative technologies and concepts in the field of renewable energy. They help to identify and promote promising new technologies and approaches which can drive the energy transition and the expansion of renewable energy. There was a lack of success with fixed market premiums, so these tenders were switched to a sliding market premium.

Furthermore, other innovative concepts are also promoted. For example, on the basis of new tendering regulations (section 39o or section 39p (1) of the RES 2023), plants for the generation of electricity from green hydrogen or plant combinations of renewable energy sources with local hydrogen-based electricity storage will be supported in order to test storage in hydrogen and reconversion to electricity.

4 Agri-PV (agricultural photovoltaic combinations): Combined land use by PV systems and for agricultural production (e.g. for fruit tree plantations).
Floating PV (floating photovoltaic systems): floating PV systems, for example on open-cast mining waters such as gravel pits.
Peatland PV: PV systems on agriculturally used peatland soils. The prerequisite for funding is the rewetting of these drained moor soils. On the one hand, this is intended to promote rewetting as a contribution to climate protection and, at the same time, the areas can be used for PV electricity generation.

Current information on bidding deadlines, tender volumes and award lists for the individual technologies is published on the Federal Network Agency website (in German only).

Offshore Wind Energy Act (WindSeeG)

The expansion paths and tender quantities for offshore wind energy are not regulated in the RES, but in the Offshore Wind Energy Act (WindSeeG) [10]. The law was fundamentally revised in order to implement the planned greatly accelerated expansion. In order to achieve the minimum expansion targets of 30 gigawatts by 2030, 40 gigawatts by 2035 and 70 gigawatts by 2045, steps were taken to expedite planning and approval procedures: In the future, offshore grid connections can be awarded directly after the area has been included in the development plan, which will speed up the awarding of contracts by several years.

- In the case of centrally pre-surveyed areas, the planning approval procedure is no longer required and has been replaced by a planning authorisation procedure.
- Specifications for the duration of planning approval and planning authorisation procedures have been added.
- Environmental assessments and participation rights will be more strongly bundled.
- The technical supervision duties of the Federal Maritime and Hydrographic Agency have been bundled with the BMWK for all tasks related to the Offshore Wind Energy Act.

The amendment also regulates the subsequent utilisation and repowering of existing offshore wind farms and introduces requirements for the planning and approval of hydrogen pipelines.

Further information on the topic of Offshore Wind Energy and the Act can be found on the BWMK website (in German only).

Furthermore, transfer of surcharges in the electricity sector was standardised and regulated in the new Energy Financing Act (EnFG) (see also the following chapter). These measures are intended to reduce bureaucracy and at the same time make various business models more economically attractive. Landlord-to-tenant electricity supply or storage projects, for example, will benefit from this.

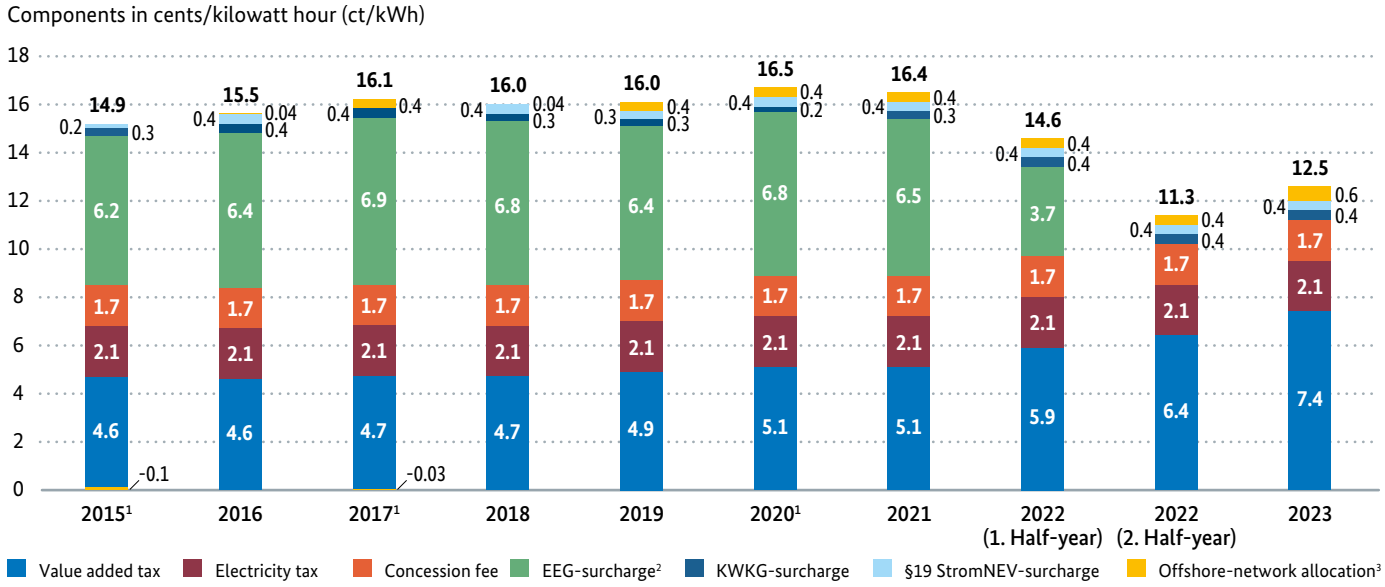
Cross-border cooperation with neighbouring countries in the promotion of renewable energy was also further developed by law.

RES surcharge and its abolition

In order to absorb the rising energy prices, the German government initially reduced the RES surcharge to zero on 1 July 2022 and abolished it completely on 1 January 2023 when the Energy Financing Act (EnFG) came into force. This brought an end to RES subsidies via the electricity price. The funding requirements for renewable energy will be financed from federal budget funds in future. This relieves the burden on private households and the economy. The two remaining surcharges in the electricity sector, the surcharge under the Combined Heat and Power Act (KWKG) and the offshore grid surcharge, have been standardised. Furthermore, a reliable and predictable legal basis has been created for industry by transferring the special equalisation scheme, which is now only required for the Combined Heat and Power Act levy and the offshore grid levy, to the EnFG and simplifying it significantly. Sections 28 ff EnFG contain the main new provisions, e.g. for electricity cost-intensive companies. Further information on the special equalisation scheme is published on the Further information on the special equalisation scheme is published on the BAFA website (in German only).

The development of taxes, levies and charges for private households and industry are shown in Figures 25 and 26.

Figure 25: Taxes, levies and surcharges for households



Due to the very low totals (< 0.01), the allocation for switchable loads is not shown
Individual values can be viewed at BDEW electricity price analysis (in German only)

1 19% VAT in 2020

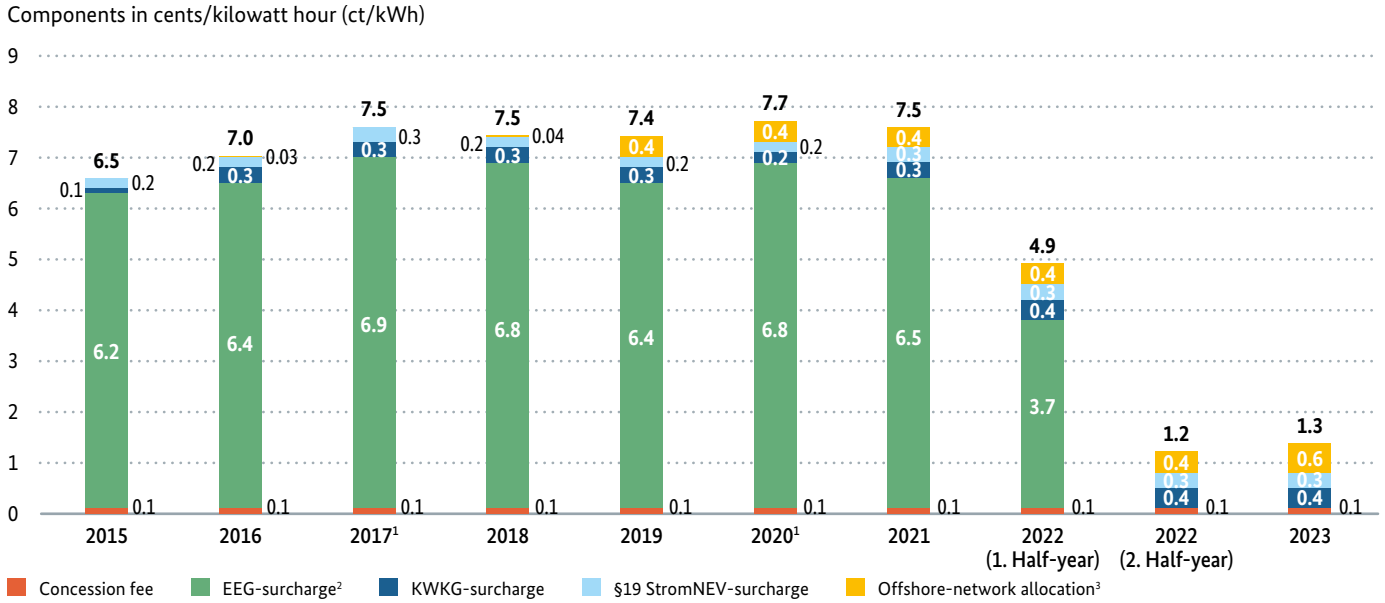
2 No RES surcharge from 1 July 2022

3 Offshore grid surcharge 2015/17 negative due to subsequent offsetting (2015: -0.051 ct/kWh, 2017: -0.028 ct/kWh)

Source: German Association of Energy and Water Industries (BDEW) [11]

The abolition of the RES surcharge will also ease the burden on industry. Electricity cost-intensive sectors that are in international competition and certain industries (including railways, shore-side power plants) were already partially exempt from paying the RES surcharge through the 'special equalisation scheme'.

Figure 26: Taxes, duties and levies for industry in ct/kWh (without electricity tax)



Due to the very low totals (< 0.01), the allocation for switchable loads is not shown
Individual values can be viewed at BDEW electricity price analysis (in German only)

1 19% VAT in 2020

2 No RES surcharge from 1 July 2022

3 Offshore grid surcharge 2015/17 negative due to subsequent offsetting (2015: -0.01 ct/kWh, 2017: -0.00 ct/kWh)

Sources: German Association of Energy and Water Industries (BDEW) [11]

Electricity from renewable energy sources outside the RES

Wholesale prices for gas and electricity in Germany have fallen significantly compared to their peak levels of summer 2022, but industry still needs competitive energy prices in order to continue to compete globally. High electricity prices pose a problem for the transformation of industry towards climate neutrality in which electrification and hydrogen play a central role. The BMWK has therefore prepared a working paper on an industrial electricity price in which a two-stage concept is proposed to enable industry to purchase electricity at internationally competitive prices. A long-term 'transformation electricity price' should make electricity from renewable energy sources available to industry at favourable prices. Until this transformation electricity price takes effect, a 'bridge electricity price' for energy-intensive companies is to be introduced for a transition period.

The BMWK has proposed a number of measures for the implementation of the transformation electricity price. One measure is to support direct contracts between industrial consumers and operators of renewable energy plants, known as power purchase agreements (PPAs). These enable operators of renewable energy plants to enter into bilateral purchase agreements without claiming RES funding. The closing of PPAs is to be secured with guarantees in order to reduce their risk premiums. At the same time, access to PPA models will also be improved for medium-sized companies.

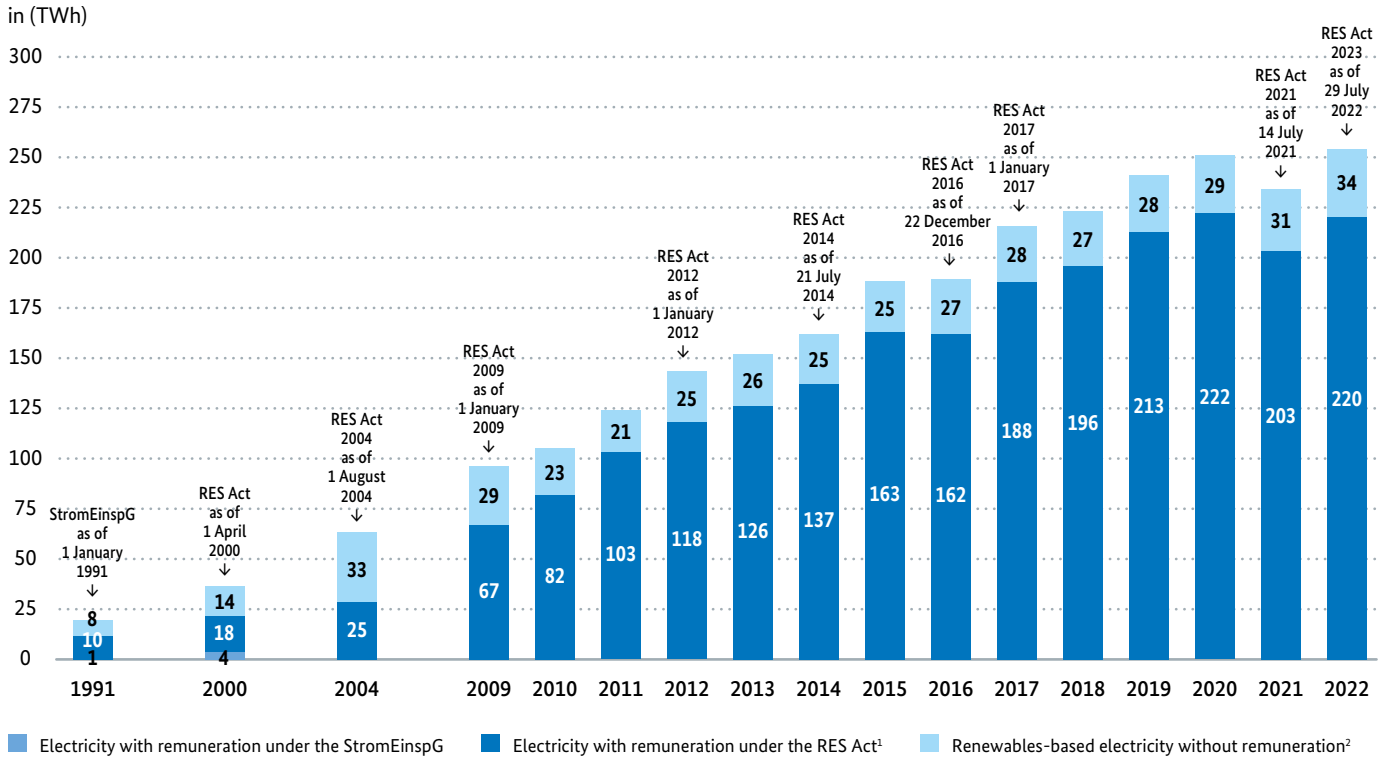
There has already been an increase in direct 'green' electricity supply contracts for several years, including for old systems (especially wind-powered installations on land) whose 20-year RES subsidisation period had expired or for PV systems being built without RES funding.

Under a PPA, all conditions are set out in the contract, including the amount of electricity, the agreed costs and the taxation arrangements. PPAs offer industrial companies the option of hedging against fluctuating electricity prices. Since the 2022 revision of the Electricity Price Compensation Funding Directive, it is possible for companies to purchase electricity through PPA contracts and claim electricity price compensation at the same time. With the Energy Financing Act, the German government has introduced a 'green bonus' for electricity-intensive companies under a special equalisation scheme if they cover part of their green electricity consumption through PPAs.

PPAs are categorised as other 'direct marketing' (DM), in which plant operators sell power on the electricity exchange to a direct marketer or to an end consumer directly. In 2022, around 12 gigawatts of capacity were marketed as other DM. This means that the marketed capacity has doubled within a year (6 gigawatts in 2021) [12]. At the beginning of 2022, other DM output growth was mainly due to post-RES systems (power plants older than 20 years) having left the RES at the end of the subsidisation period. In the middle of the year, it was mainly existing RES plants that switched to other DM to optimise revenue. PPA-financed new installations also played a role in 2022, albeit to a lesser extent. Since PPAs are bilateral contracts, there is no publicly available data on PPA structures [12].

As figure 27 shows, the electricity not subsidised under the RES has so far accounted for only a small portion of total electricity generation from renewable energy sources.

Figure 27: Electricity generation from renewable energy sources with and without entitlement to remuneration under the Electricity Feed-in Act and RES Act



1 Electricity consumed on-site, fed into the grid and remunerated under the RES Act

2 Electricity generated from large hydropower plants and biomass (combusted alongside regular fuel in conventional power stations, including the biogenic share of waste) and electricity from solar power installations that is fed into the grid and consumed on site and for which there is no entitlement to remuneration under the RES Act.

Source: Federal Ministry for Economic Affairs and Energy, based on data provided by the German transmission system operators (TSOs [13])

Expansion of photovoltaics

Photovoltaics (PV) are an important pillar in the transformation to a sustainable and greenhouse gas-neutral electricity supply and are already one of the most important sources of electricity generation today. By 2030, 215 gigawatts of PV are to be installed in Germany, with roughly half of the expansion taking place on rooftops and half on the ground.

In order to achieve the Federal Government's ambitious PV expansion targets, the Cabinet adopted the 'Solar Package' on 16 August 2023. The Solar Package contains a large number of measures designed to accelerate the expansion of ground-mounted and rooftop installations and to strengthen citizen participation. Further information on the Solar Package is published at BMWK (in German only).

Ground-mounted PV systems

In addition to the forced expansion of photovoltaics on roof surfaces, expansion in open spaces is also necessary to achieve the target. Around two thirds of the photovoltaic capacity installed in Germany currently consists of roof-mounted systems and one third is ground-mounted systems [14]. The Federal Government's PV strategy foresees an annual expansion of around 11 gigawatts of ground-mounted PV systems from 2026 onwards so that half of the expansion will take place in open area sites in future. Ground-mounted PV systems are currently the more cost-effective power generation technology and enable rapid, plannable PV expansion. Compared to roof systems, the components (modules, inverters, cables, etc.) can generally be procured more cost-effectively due to the larger quantities. The Federal Government is combating competition for

space with intelligent concepts and innovations. Biodiversity solar parks, which create new habitats for flora and fauna, are to become as commonplace as agri-PV in agriculture or peatland PV on rewetted moorland.

Photovoltaic systems on multi-party buildings

In the context of the current legislation surrounding the Solar Package and the strengthening of citizen participation in the expansion of renewable energy, this section presents various participation models.

The operation of photovoltaic systems on multi-party buildings (in German only) is essentially based on the following concepts:

- full feed-in model (with increased feed-in tariff or market premium) or
- landlord-to-tenant electricity marketing models (with or without RES tenant electricity surcharge) and surplus feed-in (with feed-in tariff or market premium) or
- plug-in solar systems ('balcony power plants').

The BMWK developed further measures as part of the Solar Package to enable the wider use of PV roof systems in the landlord-to-tenant electricity sector.

Full feed-in model

The increased RES full feed-in tariff for solar installations is a comparatively uncomplicated and reliably calculable funding option, especially for the development on the roofs of multi-party or rented residential buildings. If a plant operator feeds all of the electricity generated by the PV plant into the grid, they can claim an increased feed-in tariff or, depending on the form of RES sale, an increased market premium in accordance with the new legal requirements (Section 48 (2a) RES Act 2023). The PV systems are operated completely independently of the supply and electricity contracts of the end consumers in the building. Because this type of tenant electricity project does not fall under the RES, no 'tenant electricity surcharge' can be applied to the electricity fed into the grid.

Further information and the current remuneration rates can be found at the Federal Network Agency under Fördersätze für Solaranlagen und Mieterstromzuschlag ('Subsidy rates for solar installations and tenant electricity surcharge', in German only).

Landlord-to-tenant electricity models

The landlord-to-tenant electricity supply model is a concept in which the electricity generated on site from renewable energy sources is sold to the end consumers of a residential building. Residents benefit from cheaper and environmentally friendly electricity while the operator of the tenant electricity system has an additional source of income and contributes to the energy transition.

Landlord-to-tenant electricity supply models vary in practice. These marketing models generally share the following features

- the electricity is generated on site with a solar system, a CHP unit or a similar generation system;
- power is supplied primarily to the residents of the building (without using the public grid) within the customer system and consumed in the building; and
- electricity is fed into the grid as 'surplus feed-in'.

This type of model has been in use for many years. It is available in different variants with or without RES tenant electricity subsidisation. What the models have in common is that no grid fees, levies or charges are incurred for the landlord-to-tenant electricity supply generated, supplied and consumed within the customer's system. A significant share of the profitability generally results from the avoided levies and surcharges. So far, however, the expansion of tenant electricity systems has fallen well short of expectations, as the Federal Government's tenant electricity report [15] emphasises. As a result, the funding conditions were further improved under the RES 2021 and RES 2023.

Detailed information on these topics can be found under Mieterstrom-Modelle on the Federal Network Agency's website ('Landlord-to-tenant electricity supply models', in German only).

The amount of the tenant electricity surcharge depends on when the system was commissioned and is then valid for 20 years. Just as with the feed-in tariff, the amount of the tenant electricity surcharge is subject to degression, i.e. it decreases continuously. The current tenant electricity surcharges are published by the Federal Network Agency on the website under Fördersätze für Solaranlagen und Mieterstromzuschlag ('Subsidy rates for solar installations and tenant electricity surcharges', in German only).

The potential for solar power generation on apartment blocks is far from being exhausted. A 2017 study commissioned by the BMWK on the topic of landlord-to-tenant electricity supply concluded that up to 3.8 million flats could theoretically be supplied with landlord-to-tenant electricity. This corresponds to around 18% of all rental flats. However, according to analyses of the Core market data register (in German only), only around 6,700 PV tenant electricity systems with RES tenant electricity surcharges and a capacity of around 130 megawatts have been registered as of June 2023.

Further up-to-date information on the topic of landlord-to-tenant electricity supply can also be found on the website of the Federal Ministry of Economics (in German only).

Balcony power stations

Balcony power stations are small photovoltaic systems that can be installed on a balcony or terrace. They are used for decentralised power generation and enable private households to generate their own solar power.

A balcony power station usually consists of solar modules, an inverter and a connection cable via which the PV electricity is fed directly into the household power grid. The inverter ensures that the direct current generated is converted into standard household alternating current.

Balcony power stations are currently allowed a maximum output of 600 watts (the Federal Government plans to increase this as part of the solar package). This usually corresponds to the output of two modules. They are therefore not designed to cover a household's entire electricity requirements, but rather to reduce the amount of electricity drawn from the grid. The solar power generated can be used directly in the household and surpluses can be fed into the public grid.

Balcony power stations are relatively easy to install and generally do not require any complex authorisation procedures. Furthermore, the German government is planning to simplify their commissioning via a measure within the Solar Package. To this end, registration with the grid operator is to be omitted and registration in the Core market data register is to be limited to a small amount of data very easy to enter [15]. Detailed information on the requirements and obligations can be found on the website of the Federal Network Agency (in German only).

Balcony power plants offer tenants in particular an opportunity to utilise solar energy, even if they do not have their own roof. According to industry figures, there are more than 250,000 of these systems installed in Germany with a total capacity of an estimated 100 megawatts [16].

Economic impetus through the construction and operation of renewable energy installations

Investment in renewable energy as an economic factor

With the expansion of the use of renewable energy sources in Germany, the RE sector has established itself as an important economic factor. Economic stimuli are generated by investments in the expansion of RE, but also by the operation and maintenance of the installations.

The development of investments is determined by two factors: the increase of capacities and the cost development of the individual technologies.

The previous peak value for investments in renewable energy installations was reached in 2010 at just under €28 billion. After that, investments fell to a low of €10.6 billion in 2019, while at times fluctuating. Since then, an upward trend has been observed again and in 2022 alone, a year-on-year increase of 51% to € 21.9 billion was recorded. Germany as a business location continues to benefit greatly from these investments since a large proportion of the value added during the manufacture and installation of the systems is generated in Germany [17].

The development of investments and operating costs in 2022 was strongly marked by the shortage of and associated increase in the price of fossil fuels, which began in 2021 and intensified massively in the course of 2022 as a result of the Russian war of aggression against Ukraine. The energy (price) crisis led to a sharp short-term increase in demand for heating systems based on renewable energy sources, but also for PV systems for generating electricity in private homes. This surge in demand fuelled the increase in the cost of goods and services (which had already risen due to higher commodity and energy prices), which also led to sharp increases in the price of equipment, particularly in the heating sector. While price increases for larger systems, i.e. primarily commercial systems with longer realisation periods, are likely to have less of an impact in the short term, the effects on smaller projects, particularly in the area of building heating systems, were felt in the short term.

In the photovoltaic systems sector, the 51% year-on-year growth in investments totalling €7.9 billion primarily reflects the strong expansion of systems. This also applies to investments in onshore wind power plants, which increased by more than a quarter year-on-year to €3.6 billion. In the case of offshore wind-power, projects awarded contracts from the 2017 and 2018 tenders reached the implementation phase, meaning that investments increased again significantly after a two-year dry spell.

The strong investment growth in the area of ambient heat utilisation (heat pumps) and wood-fired heating systems was due to a large increase in the number of systems as well as to significantly higher system prices. The increase in investment compared to the previous year is 82% for heat pumps, 36% for systems utilising heat from biomass and 25% for solar thermal systems. Investments in plants for generating electricity from biomass and hydropower fell by 26% and 14% respectively in 2022 compared to the previous year.

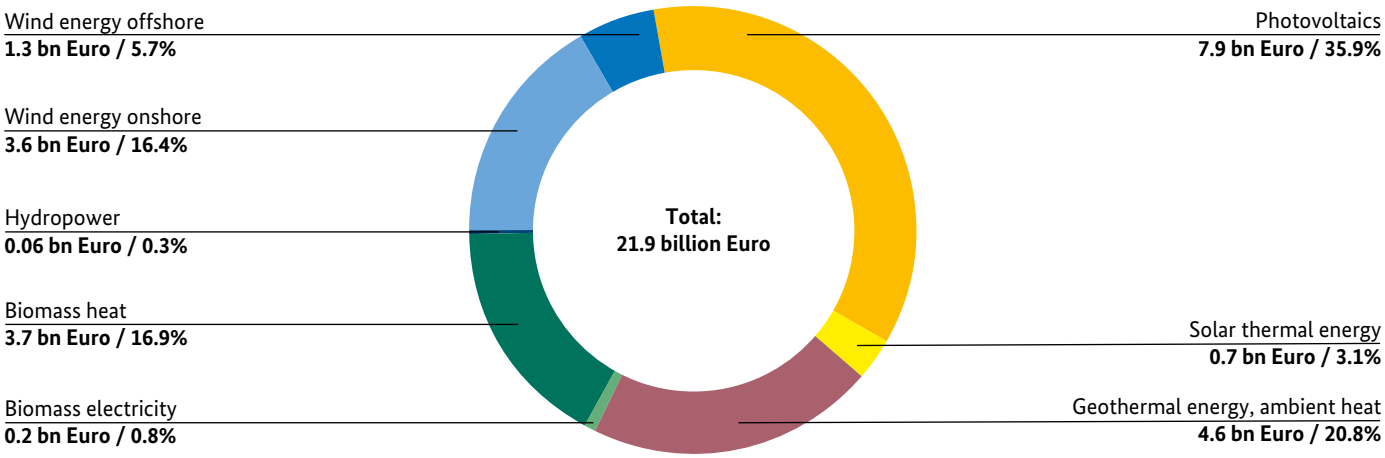
At just under 59%, the largest share of the investments reported is still attributable to electricity generation plants subsidised under the RES. Compared to the previous year, this was down by half a percentage point.

Table 15: Investment in the building of renewable energy installations

	Hydro-power	Wind energy onshore	Wind energy offshore	Photo-voltaics	Solar thermal energy	Geothermal energy, ambient heat	Biomass electricity	Biomass heat	Total
	(billion €)								
2000	0.5	1.9	–	0.3	0.4	0.1	0.5	0.9	**4.7**
2005	0.2	2.5	–	4.8	0.6	0.4	1.9	1.5	**12.0**
2006	0.2	3.2	–	4.0	1.0	0.9	2.3	2.3	**14.0**
2007	0.3	2.5	0.0	5.3	0.8	0.9	2.3	1.5	**13.6**
2008	0.4	2.5	0.2	8.0	1.7	1.2	2.0	1.8	**17.7**
2009	0.5	2.8	0.5	13.6	1.5	1.1	2.0	1.6	**23.6**
2010	0.4	2.1	0.5	19.6	1.0	1.0	2.2	1.2	**27.9**
2011	0.3	2.9	0.6	15.9	1.1	1.0	3.1	1.3	**26.1**
2012	0.2	3.6	2.4	12.0	1.0	1.1	0.8	1.5	**22.5**
2013	0.1	4.5	4.3	3.4	0.9	1.1	0.7	1.6	**16.5**
2014	0.1	7.1	3.9	1.5	0.8	1.1	0.7	1.3	**16.4**
2015	0.1	5.4	3.7	1.5	0.8	1.0	0.2	1.3	**13.9**
2016	0.1	6.9	3.4	1.6	0.7	1.2	0.3	1.2	**15.3**
2017	0.1	7.5	3.4	1.7	0.5	1.3	0.3	1.2	**15.9**
2018	0.1	3.4	4.1	2.6	0.5	1.5	0.4	1.2	**13.8**
2019	0.1	1.6	2.1	3.4	0.4	1.4	0.4	1.3	**10.6**
2020	0.1	2.1	0.1	4.8	0.5	1.9	0.3	1.9	**11.7**
2021	0.1	2.8	0.3	5.2	0.6	2.5	0.2	2.7	**14.5**
2022	0.1	3.6	1.3	7.9	0.7	4.6	0.2	3.7	**21.9**

Source: Calculations made by the Centre for Solar Energy and Hydrogen Research (ZSW); rounded figures

Figure 28: Investment in the building of renewable energy installations, 2022



Most of the investment represented here was used for building new installations, with a smaller share being used for expanding or upgrading existing installations, for example for re-activating old hydroelectric power stations. The chart includes not only investment made by utilities, but also investment from industry, the commercial sector, trade, and private households.

Source: Calculations made by the Centre for Solar Energy and Hydrogen Research (ZSW); rounded figures

Lasting impetus from plant operation

In addition to investment, plant operation also bears considerable economic significance. Plant operation (including maintenance) gives economic impetus to other sectors through demand for personnel, electricity (auxiliary energy), spare parts or fuel. Operating costs incurred by the plant operator leads to corresponding revenues for suppliers, among others. The economic stimulus from plant operation has risen steadily in past years in tandem with the increasing number of installations. From the year 2000 until 2022, revenues rose from just under €2 billion to almost €24 billion so that economic stimulus from operations has exceeded investment in the construction of plants since 2015.

In contrast to the other renewable installations, biomass plants require fuel to generate electricity and heat. The associated costs make biomass plants account for the largest share of the total economic impetus from plant operation. The second largest share is accounted for by revenues from the sale of biofuels, which increased significantly in 2022 due to the sharp rise in fuel prices compared to the previous year. Further impulses result from the operation of wind energy installations, geothermal and ambient heat utilisation plants as well as PV, solar thermal and hydropower installations. These economic impulses give lasting strength to the economy as they accrue over the entire lifetime of an installation (usually at least 20 years for RES funded electricity) and continue to grow with each additionally installed plant.

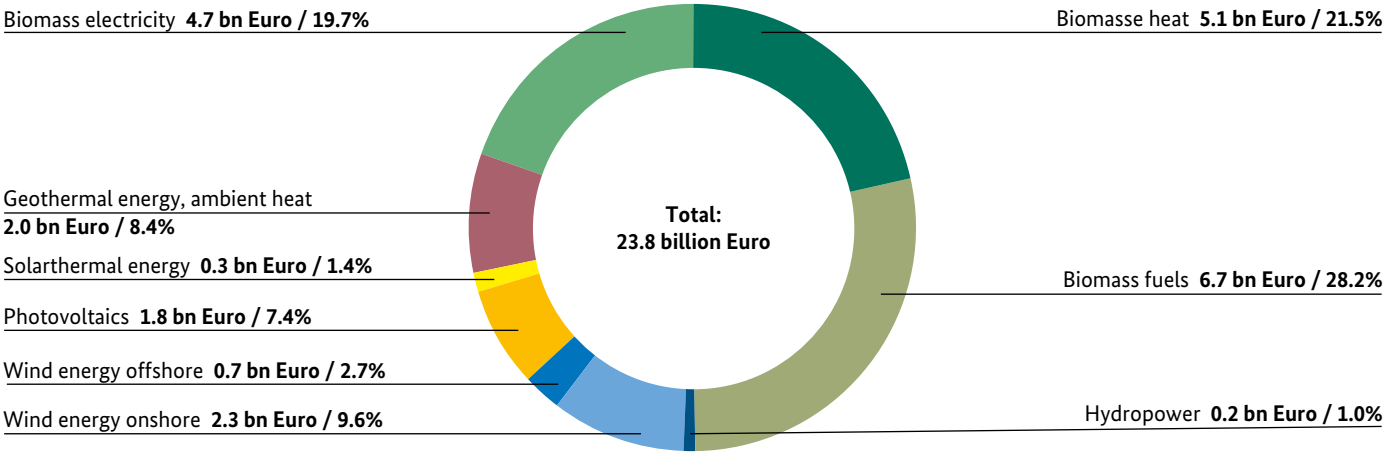
A breakdown of the various components of economic impulses shows that the current development reflects the above-mentioned cost-relevant effects of the energy price crisis: in 2000, heat

Table 16: Economic impetus from the operation of renewable energy installations

	Hydro-power	Wind energy onshore	Wind energy offshore	Photo-voltaics	Solar thermal energy	Geother-mal energy, ambient heat	Biomass electricity	Biomass heat	Biomass fuels	Total
	(billion Euro)									
2000	0.1	0.2	–	0.01	0.0	0.2	0.2	1.1	0.2	**1.9**
2005	0.1	0.6	–	0.1	0.1	0.2	0.7	1.5	1.8	**5.1**
2006	0.1	0.6	–	0.2	0.1	0.3	1.1	1.7	3.2	**7.3**
2007	0.1	0.7	–	0.3	0.1	0.4	1.7	2.0	3.8	**9.0**
2008	0.2	0.8	–	0.4	0.1	0.4	2.0	2.2	3.5	**9.6**
2009	0.2	0.9	0.01	0.5	0.1	0.5	2.4	2.5	2.4	**9.5**
2010	0.2	1.0	0.02	0.8	0.2	0.6	2.9	2.9	2.9	**11.4**
2011	0.2	1.1	0.03	1.0	0.2	0.7	3.3	2.9	3.7	**13.1**
2012	0.2	1.2	0.06	1.3	0.2	0.8	4.1	3.1	3.7	**14.7**
2013	0.2	1.4	0.1	1.4	0.2	0.9	4.2	3.3	3.1	**14.8**
2014	0.2	1.6	0.2	1.4	0.2	1.0	4.5	3.0	2.6	**14.8**
2015	0.2	1.7	0.3	1.4	0.3	1.1	4.7	3.2	2.4	**15.2**
2016	0.2	1.9	0.4	1.4	0.3	1.1	4.6	3.4	2.6	**15.9**
2017	0.2	2.1	0.4	1.5	0.3	1.2	4.7	3.4	2.7	**16.5**
2018	0.2	2.2	0.5	1.5	0.3	1.3	4.7	3.3	2.7	**16.8**
2019	0.2	2.3	0.6	1.5	0.3	1.5	4.8	3.4	2.8	**17.3**
2020	0.2	2.3	0.6	1.6	0.3	1.6	4.8	3.4	3.5	**18.4**
2021	0.2	2.3	0.6	1.7	0.3	1.8	4.6	3.8	5.0	**20.3**
2022	0.2	2.3	0.7	1.8	0.3	2.0	4.7	5.1	6.7	**23.8**

Source: Calculations made by the Centre for Solar Energy and Hydrogen Research (ZSW); rounded figures

Figure 29: Economic impetus from the operation of renewable energy installations, 2022



Source: Calculations made by the Centre for Solar Energy and Hydrogen Research (ZSW); rounded figures

plants still accounted for two-thirds of the total, while electricity and fuels accounted for 22% and 11%, respectively. By 2019, the share of electricity generation plants and fuels had grown to 54% and 16% respectively, while that of heat generation plants fell to 29%. From 2020 to 2022, the share of electricity generation plants fell to 40%, while the shares of heat generation plants and revenue from the sale of biofuels rose to around 31% and 28% respectively.

For more on the methodology used, see the section 'Information on Methodology'.

Employment in the renewable energy sector in Germany

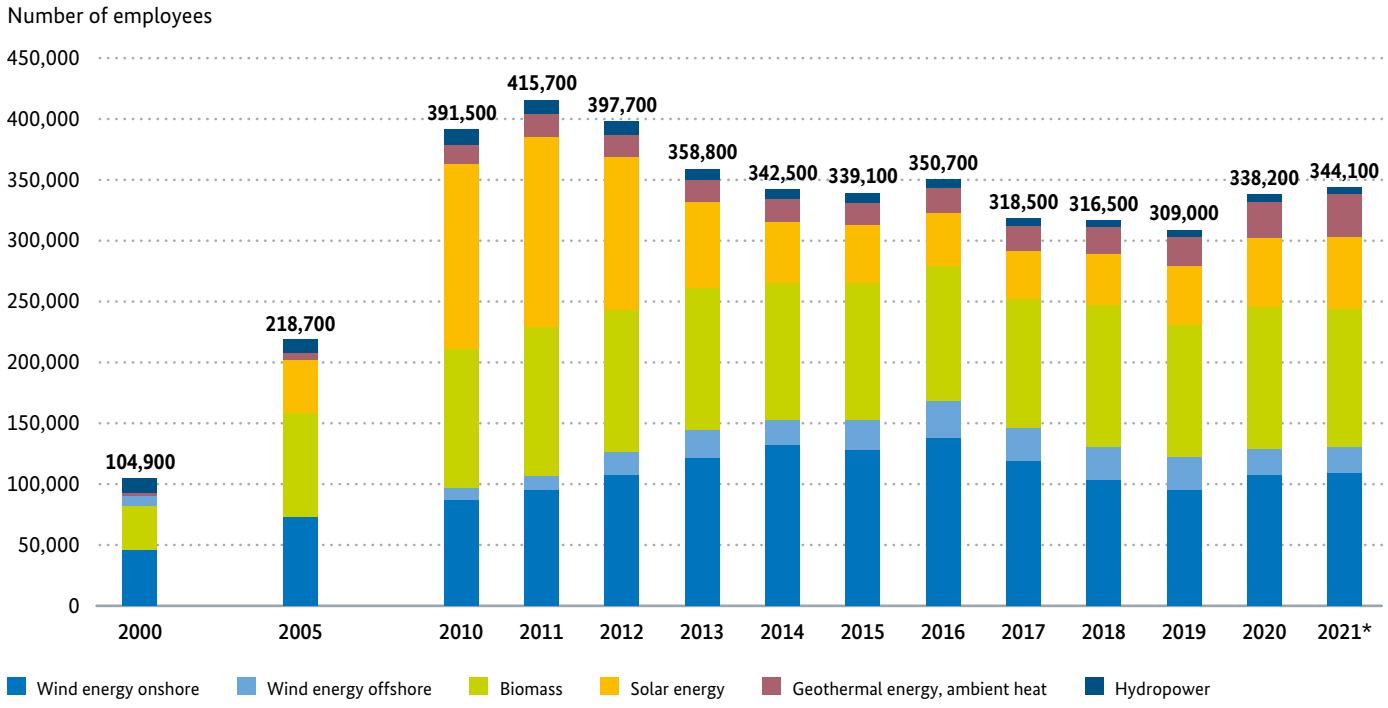
According to preliminary projections for 2021 (figures for 2022 were not available by the editorial deadline), employment figures in the renewable energy sector increased slightly by 2% to around 344,100 people in 2021. This was about 6,000 people more than in the previous year (338,200 people).

If the development of employment is broken down by technology, different trends between the last few years become clear. They are primarily related to the roll-out of the various technologies. For example, employment in the onshore wind energy sector rose to around 138,000 people by 2016 and then, despite an increasing export share, fell by around 38% to around 95,000 employees within three years as a result of the lower installation figures in Germany. Due to the slight increase in the number of wind turbine installations in the last two years, the number of employees rose again to around 109,000. The same trend was seen in offshore wind energy up to 2016. The number of employees had risen to 29,800 by then, but then fell by around 27% in recent years to around 21,700 in 2021 due to the very low level of new installations.

Biomass use is characterised by a variety of technologies, some of which developed very differently during the period under review. After an initial increase, employment in these areas remained at a relatively constant level and contributed about 37% (about 114,000 people) to employment in the renewable energy sector in 2021.

Employment in the solar energy sector has experienced the greatest fluctuations in the period under review from 2000 to 2021. After a very strong increase in employment until 2011, when solar energy accounted for the largest share of employment in the renewable energy sector with 38% (156,700 people), it declined more than 70% by 2017. It was only in 2018 that this development came to an end and a renewed increase in employ-

Figure 30: Development of gross employment from renewable energy in Germany



* figures are provisional

Sources: DIW, DLR, GWS [18]

ment figures was recorded due to higher photovoltaic installation figures. In 2021, around 58,500 people were employed in the solar energy sector.

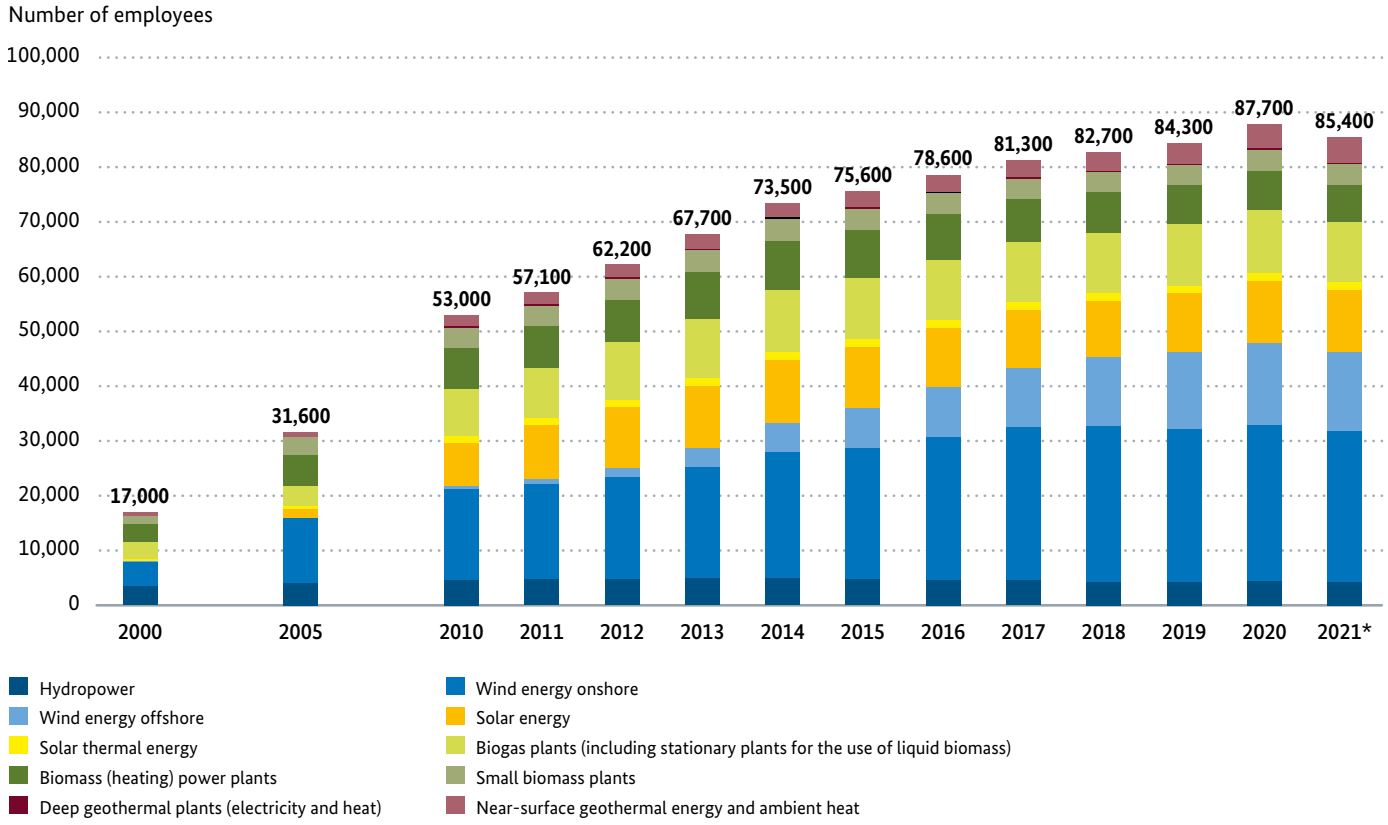
Geothermal energy contributed 10% to employment in 2021. There was an increase of 20% to around 36,000 employees due to the strong demand for heat pumps.

The employment trend in the hydropower sector, on the other hand, is characterised by the fact that this technology, and with it the associated industry, had already reached a very high degree of maturity in 2000. The tendency is for employment to decline. In 2021, hydropower contributed only about 2% of total employment in the renewable energy sector with 5,700 people.

In the area of operation and maintenance of renewable energy installations, there has been for the first time a slight decrease in employment figures compared to the last few years. This is mainly due to special circumstances of the Corona pandemic (e.g. short-time work).

In 2000, about 17,000 people were employed in the operation and maintenance of renewable energy installations. Employment figures increased 5-fold to 87,700 by 2020. In 2021, employment figures in these sectors fell for the first time by about 3% to a total of 85,400 persons. With about 32%, the onshore wind energy sector employed the most people in maintenance and operation of plants, followed by offshore wind energy with 17%, photovoltaics and biogas plants with 13%. Biomass (heating) power plants continued to contribute 12% to employment. Small-scale biomass plants, hydropower and also near-surface geothermal energy and ambient heat each again had a share of just under 5%, solar thermal energy about 2%. Deep geothermal plants are still at a low level of expansion so that the resulting employment contributes less than 1% to the total [18].

Figure 31: Development of employment in the operation and maintenance of renewable energy installations in Germany



* figures are provisional

Sources: DIW, DLR, GWS [18]

Legislation and promotion of renewable energy in the building sector

In private households, over 90% of final energy is consumed for heating applications. Around two-thirds of this are accounted for by final energy consumption for space heating alone. In the trade, commerce and services sector (TCS) as well, heating applications dominate final energy consumption accounting for over 60% [19]. For the provision of heating and cooling in the building sector alone, around 120 million tonnes of CO_2-eq. were emitted. The Federal Climate Change Act (KSG), which is expected to be amended again in 2023, will report this value as the annual emissions volume for the building sector. By 2045, the Federal Government wants to realise a nearly climate-neutral building stock. The agreement of the 'Ampel coalition' set the target for 50% climate-neutral heating by 2030. To achieve these goals, houses and buildings must be made significantly more energy-efficient and the share of renewable energy in heat consumption must be massively increased [20].

Buildings Energy Act (GEG)

With the Buildings Energy Act (GEG), the German government has created an overall strategy for the building sector. The Act came into force on 1 November 2020 and replaces the regulations of the Energy Conservation Act (EnEG), the Energy Conservation Ordinance (EnEV) and the Renewable Energies Heat Act (EEWärmeG). Furthermore, within the framework of the GEG, the Federal Government is implementing the EU Buildings Directive (Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010), which sets the standard for new buildings as of 2021 as the nearly zero-energy building.

The most important regulations in the GEG are:

- specifications for heating and air conditioning technology as well as the thermal insulation standard and heat protection of buildings;
- retrofitting and replacement obligations for owners of existing buildings;
- for new buildings, certain proportions of renewable energy sources are defined that must be used in the building for heating or cooling.

Furthermore, the GEG 2020 enables the recognition of electricity from renewable energy sources as an option for meeting the requirements. Electricity from renewable energy sources can thus contribute to meeting the heating and cooling demands of buildings in the same way as solar thermal energy. In addition, the GEG offers the possibility of taking substitute measures instead of using renewable energy sources as well as combining different measures.

In September 2023, the Bundesrat adopted the new RES (see , 'Energy Transition in the heating sector' for details.

Further information on the subject of energy conservation in the building sector is available from the Federal Institute for Research on Building, Urban Affairs and Spatial Development and on the BBSR topic portal (in German only).

Federal funding for efficient buildings (BEG)

With the Climate Action Programme 2030, the Federal Government is continuously developing funding for energy efficiency and renewable energy in the building sector. The Federal Funding for Efficient Buildings (BEG) subsidises measures for the use of renewable energy sources for heat generation and greater energy efficiency in residential and non-residential buildings, including the replacement of old, fossil-fuelled heating systems with new heating based on renewable energy sources as well as measures to insulate the building envelope. These investment incentives are intended to make a decisive contribution to achieving the 2030 energy and climate targets in the building sector. Funding is focussed on the refurbishment of existing buildings as this is where the climate protection effect and funding efficiency are greatest.

Since 2021, the BEG has combined previous building subsidy programmes into a single subsidy programme with three sub-programmes:

1. Residential Buildings (BEG WG) – Refurbishment of residential buildings;
2. Non-residential Buildings (BEG NWG) – refurbishment of non-residential buildings;
3. Individual Measures (BEG EM) – Refurbishment with individual measures of residential or non-residential buildings.

The KfW (Kreditanstalt für Wiederaufbau) and the Federal Office of Economics and Export Control (BAFA) are responsible for implementing the BEG. Funding is provided either in the form of a non-repayable investment grant or in the form of a low-interest loan in combination with a repayment grant from Federal funds.

Individual refurbishment measures, for example replacing an old, fossil-fuelled heating system with a renewable energy-based heating system or measures to insulate the building envelope (BEG EM) are supported with a grant towards the investment costs and can be applied for at BAFA.

Systemic refurbishment of residential and non-residential buildings to the level of an efficiency house or efficiency building (BEG WG and BEG NWG) is subsidised via low-interest loans plus a repayment subsidy and can be applied for at KfW.

In order to accelerate the achievement of climate targets in the building sector, the BEG was reformed in summer and again in autumn 2022. The current terms and conditions came into force on 1 January 2023.

In 2022, a total of almost 587,000 applications to KfW and BAFA were approved under the BEG. This meant that around 1.4 million housing units could be funded. The volume of funding for building subsidies at KfW and BAFA amounted to around €28.8 billion in 2022.

Table 17: Overview of funding allowances since the start of the BEG, 2022

		Number of commitments since the start	Number of commitments for residential units since the start
BEG WG	New buildings	57,550	312,587
	Refurbishment	30,608	142,499
	Total BEG WG	**88,158**[1]	**455,086**[1]
BEG NWG	New buildings	5,533	
	Refurbishment	2,200	
	Total BEG WG	**7,733**[1]	
BEG EM	WG	469,104	963,416
	NWG	21,925	
	Total BEG EM	**491,029**	**963,416**
Total		**586,920**	**1,418,502**

1 Deviation within the categories 'New construction' and 'Refurbishment' from the 'Total' is due to non-assignable applications (due to ambiguous or missing information)

Source: BMWK [21]

KfW funding within the framework of BEG residential buildings and BEG non-residential buildings

The funded measures are designed to achieve so-called efficiency building levels when renovating or constructing new buildings. An efficiency building is characterised by energy-optimised construction and system technology and also meets the specifications defined in the minimum technical requirements for overall energy efficiency (reference value: primary energy demand) and the energy efficiency of the building envelope (reference value: transmission heat loss) for an efficiency building level. The smaller the number, the more energy-efficient a building is.

The BEG applies to all residential buildings (WG), such as detached houses, apartment blocks and residential homes as well as to all non-residential buildings (NWG) such as commercial buildings, municipal buildings or hospitals.

As of 31 December 2022, over 88,000 commitments were issued by KfW under the BEG WG, of which over 30,600 were for refurbishments and more than 57,500 for new construction. The vast majority were for EH55 in new construction with more than 39,000.

Table 18: Overview of KfW commitments for the housing sector, 2022

BEG WG	Number of commitments (01.01.22 – 31.12.2022)
New construction WG	**57,550**
New construction Efficiency House 55	6,001
New construction Efficiency House 55 EE	39,019
New construction Efficiency House 55 NH	285
New construction Efficiency House 40	168
New construction Efficiency House 40 EE	5,189
New construction Efficiency House 40 NH	2,223
New construction Efficiency House 40 Plus	4,665
Refurbishment WG	**30,608**
Refurbishment Efficient House Monument	1,389
Refurbishment Efficiency House Monument EE	1,548
Refurbishment Efficiency House 100	1,100
Refurbishment Efficiency House 100 EE	2,590
Refurbishment Efficiency House 85	1,248
Refurbishment Efficiency House 85 EE	5,304
Refurbishment Efficiency House 70	1,178
Refurbishment Efficiency House 70 EE	6,922
Refurbishment Efficiency House 55	514
Refurbishment Efficiency House 55 EE	6,661
Refurbishment Efficiency House 40	43
Refurbishment Efficiency House 40 EE	1,826
Refurbishment Efficiency House EE WPB (all steps)	285

Source: BMWK [21]

KfW issued a total of 7,733 commitments for non-residential buildings, of which 5,533 were for new construction and 2,200 for the refurbishment of existing buildings. Here too, EG 55 was the efficiency building level most in demand in new construction (2,795).

Table 19: Overview of KfW commitments for the non-residential buildings sector, 2022

BEG NWG	Number of commitments
New building NWG	**5,533**
New construction Efficiency Building 55	674
New construction Efficiency Building 55 EE	2,121
New construction Efficiency Building 40	141
New construction Efficiency Building 40 EE	2,370
New construction Efficiency Building NH (total)	227
Refurbishment NWG	**2,200**
Refurbishment Efficiency Building Monument	76
Refurbishment Efficiency Building Monument EE	179
Refurbishment Efficiency Building 100	104
Refurbishment Efficiency Building 100 EE	137
Refurbishment Efficiency Building 70	100
Refurbishment Efficiency Building 70 EE	349
Refurbishment Efficiency Building 55	73
Refurbishment Efficiency Building 55 EE	504
Refurbishment Efficiency Building 40	35
Refurbishment Efficiency Building 40 EE	632

Source: BMWK [21]

BAFA funding within the framework of BEG Individual Measures (EM)

Within the framework of the BEG EM, BAFA funds all measures in buildings (in German only) that improve energy efficiency as well as the specialised planning and construction supervision of the measures by energy efficiency experts.

In 2022, BAFA funded over 491,000 applications under the BEG for a funding volume of around €8.8 billion.

Table 20: Grant funding for individual measures as part of the BEG EM in 2022

		Number
RES Installation	**Pure RES Installation**	290,200
	oil replacement	139,540
Gas condensing boiler	**Gas hybrid**	38,060
	oil replacement	12,800
	Renewable Ready	830
Other uses without heat generator	Building shell. Plant engineering. Building supervision and heating optimisation	161,940
Total Permits		**491,030**

The data relates to commitments by BAFA for funded measures in housing units. In addition to the BAFA figures stated here, 4,900 commitments for EM were made by the KfW.

Source: BMWK [21]

In 2022, the largest share of grant funding for individual measures was again for pure RES installations. Around 60% (290,200 approved applications) were made under this funding measure.

In 2022, more than 86,000 heat pumps with an installed capacity of around 599,000 kilowatts were subsidised by BAFA as part of grant funding for BEG individual measures for renewable energy sources and the Heating with Renewable Energy programme (formerly the BAFA part of MAP).

Table 21: Grant funding for individual measures within the framework of the BEG EM and the Heating with Renewable Energy programme (formerly BAFA part of the MAP) – here funding for heat pumps (HP) 2022

	Number of permits	Installed capacity (kilowatt)
Air/water heat pumps	58,442	377,117
Water/water heat pumps	1,254	18,891
Brine/water heat pumps	14,581	129,194
Exhaust air/water heat pumps	8,382	49,102
Other	3,472	25,058
Total	**86,131**	**599,362**

Source: BMWK

This is followed by biomass heating systems with more than 57,000 funded individual measures and an installed capacity of almost 1.6 million kilowatts. Wood pellet boilers accounted for over 77% of the funded biomass systems.

Table 22: Grant funding for individual measures within the framework of the BEG EM and the Heating with Renewable Energy programme (formerly BAFA part of the MAP) – here biomass funding 2022

	Number of permits	Installed capacity (kW)
Log gasifier	7,235	207,086
Pellet stoves	622	9,848
Pellet boiler	43,975	973,915
wood chip boiler	5,337	368,909
Total	**57,169**	**1,559,757**

Source: BMWK

In 2022, about 32,000 thermal solar collector systems with a collector area of about 343,000 m² were approved for hot water heating or heating support.

Table 23: Grant funding for individual measures within the framework of the BEG EM and the Heating with Renewable Energy programme (formerly BAFA part of the MAP) – here funding for solar thermal energy 2022

	Number of permits	collector area (m²)
Flat plate collector	24,624	268,212
Tube collector	7,360	74,201
Air collector	59	731
Hybrid collector	0	0
Total	**32,043**	**343,144**

Subsidised solar collector systems since applications from 2020

Source: BMWK

For gas hybrid heating systems with renewable energy-based share of least 25% – e.g. through the integration of solar thermal energy – there is an investment subsidy of up to 30%. In 2021, more than 25,000 systems were approved.

Renewable-Ready refers to gas condensing boilers that are prepared for the subsequent integration of renewable energy sources. These are subsidised with an investment grant of up to 20%.

Table 24: Grant funding for individual measures within the framework of the BEG EM and the Heating with Renewable Energy programme (formerly BAFA part of the MAP) – here funding for other purposes

	Number of permits
Gas hybrid	10,505
Renewable-Ready	200
Heating networks	2,194
Building envelope	63,566
Plant engineering	1,772
Construction supervision	37,396
Optimisation	5,884
Total	**121,517**

Source: BMWK

Further information on the funding programme can be found on the BMWK website 'Energy Change' (in German only) as well as on the BAFA (in German only) and KfW websites.

Federal funding for heat pump development (BAW)

The funding programme is intended to make a significant contribution to the qualification of specialists, energy consultants and planners of technical building equipment. The programme started on 01.04.23 and will initially run for 30 months. The aim of the programme is to fund training courses on the design, installation and regulation of heat pumps in existing buildings. On-site coaching sessions are also funded.

Promotion of network heating

Efficient and, in the long term, greenhouse gas-neutral heating networks are a key element in the decarbonisation of the heating supply. The expansion and conversion of district heating is therefore of paramount importance for reaching climate protection goals. In order for heating networks to capitalise on their advantages, investment in the expansion of networks, climate neutral heat sources and heat storage systems is urgently needed. The Federal Government launched Federal Support for Efficient Heat Networks (BEW) (in German only) in September last year, which replaced the previous 'Heating network systems 4.0' programme.

In 2022, around 6.1 million homes were supplied with district heating (i.e. around 14.2% of all homes) [22]. The share of renewable energy sources used for district heating is currently around 20%. To achieve climate protection targets, this share must be increased. The Federal Support for Efficient Heat Networks (BEW) is thus intended to create incentives for heating network operators to invest in the construction of new networks with a high percentage of renewable energy and waste heat as well as to decarbonise existing networks. The approach of the funding is to see the heating network as a whole and to support the lengthy conversion of existing networks to renewable energy and waste heat as well as the construction of new climate-friendly heating networks. For example, municipalities, companies and cooperatives can receive grants if they build a heating network or if they convert existing heating networks to renewable energy sources and waste heat. BEW also promotes individual measures that can be implemented quickly.

Funding is provided as a grant for investment costs. Operating cost funding is also available for heat feed-in from heat pumps and solar thermal systems.

Further information can be found on the BMWK and BAFA websites. Basic information on the terms and conditions of funding as well as the application process can be found in the 'About the funding procedure' section.

In addition, measures from the previous Market Incentive Programme (MAP) for the use of renewable energy in the heating market were funded by the KfW renewable energy programme 'Premium' until the end of 2022. This programme supported particularly eligible larger systems for the use of renewable energy in the heating market with low-interest loans from KfW and with repayment subsidies financed by the BMWK.

Table 25: KfW Programme – Renewable Energy 'Premium' 2022

Measures	Number of approvals	Partial loan commitment (1,000 Euro)	Committed TGZ volume (1,000 Euro)
Solar collector systems	26	44,211	24,837
Solid biomass combustion plant	137	13,017	2,909
Biomass heating systems	6	1,304	154
Heating networks	1,496	108,312	64,933
Biogas pipeline for raw biogas	14	14,535	5,296
Large heat storage	103	10,726	3,653
EE-renewable heat storage	4	102	85
Heat pumps	3	1,352	154
Others	2	15,871	4,025
Total	**1,791**	**210,432**	**106,046**

Source: BMWK

Further information on the funding programme can be found on the BMWK website 'Energy Change' as well as on the BAFA and KfW websites.

Promotion of renewable energy in transport

Mobility is essential for everyday life. But it is also one of the largest sources of greenhouse gases in Germany. With a share of around 20% of total CO_2 emissions (148 million tonnes of CO_2-equivalents) in 2022, the transport sector is the third largest source of greenhouse gas emissions after the energy sector and industry. Approximately 98% are attributable to road traffic. The 2022 sector target of the Federal Climate Change Act (KSG) was thus exceeded by around 9 million tonnes of CO_2-eq. This failure to meet the target emphasises the need to adjust climate protection in the transport sector [23].

On 21 June 2023, the Federal Government launched a comprehensive revision of the Federal Climate Change Act. The law provides for a climate protection programme with measures in the areas of transport, energy, buildings, industry and agriculture. The 2023 Climate Action Programme envisages changing drive systems in road transport as a central to a climate-friendly transport sector. This would also enable affordable individual mobility in the future and usher in a new era for Germany as an automotive centre. The Federal Government, car manufacturers and trade unions have jointly set themselves the goal of 15 million fully electric vehicles on Germany's roads by 2030. To reach the target, a significant increase in new registrations of battery electric vehicles is required over the next few years. The Federal Government therefore plans to work with industry to monitor developments and decide on further measures as necessary. Substantial funds will be made available for this purpose in the coming years. In addition to the modernisation and expansion of the rail network, measures for private transport in the areas of electrification and e-fuels have been adopted.

Further information and a list of planned measures are available in the Federal Government's '2023 Climate Action Programme'

Biofuels and alternative fuels

Biofuels such as bioethanol and biodiesel have been contributing to climate protection and the energy supply for years. For the further necessary reduction of greenhouse gas emissions from transport according to the targets set in the Renewable Energy Directive (EU) 2018/2001 (RED II), which is due to be revised in 2023, the trend is increasingly moving away from high-emission fossil fuels and conventional biofuels towards direct electrification of transport, advanced biofuels and synthetic as well as alternative fuels. Advanced biofuels are produced from waste, residues or forest wood. Alternative fuels refer in particular to CNG (com-

pressed natural gas), LNG (liquefied natural gas) and LPG (liquefied petroleum gas) from renewable sources instead of fossil natural gas. Synthetic fuels are produced using synthesis gas. If the latter is electricity-based, Power-to-X (PtX) fuels are produced. Biogenic synthesis gas is referred to as biomass-to-X (BtX) fuel.

The main targets for the biofuels sector are set throughout the EU. According to the requirements of the Renewable Energy Directive (RED II), member states have the choice between

- the binding target of reducing greenhouse gas intensity in the transport sector by 14.5% by 2030 through the use of renewable energy sources, or
- the binding target of achieving a share of renewable energy sources in final energy consumption in transport of at least 29% by 2030.

Furthermore, a binding sub-target was set requiring the share of renewable energy sources provided for the transport sector to be 5.5% advanced biofuels (generally from non-food feedstocks) and renewable fuels of non-biogenic origin (mostly renewable hydrogen and hydrogen-based synthetic fuels). This target requires Member States to ensure that the share of renewable energy sources provided for the transport sector in 2030 is at least 1% renewable fuels of non-biogenic origin.

At the same time, an EU-wide ramp-up of e-fuels in aviation was agreed to in the agreement ReFuelEU Aviation (which has been the law in Germany since 2021) which now applies EU-wide. The German e-fuels quota (2% by 2030) was the worldwide first commitment to the use of such fuels. Across the EU, at least a 1.2% share of e-fuels must be used from 2030 and 2% from 2032. The quota increases to 35% by 2050. In total, at least 70% of aviation fuels must come from renewable energy sources by the target year 2050, including biofuels from residual and waste materials as well as e-fuels.

In addition to extensive measures planned by the Federal Government as part of the 2023 climate protection package to promote e-fuels, the BMWK has been promoting green hydrogen ('green' because it is produced from renewable energy), PtX fuels and advanced biofuels for years. From the perspective of energy research, the greatest challenges include the further development of innovative mobility concepts as well as alternative, low-emission drive technologies. Hybrid systems consisting of batteries and combustion engines or fuel cells, for example, are to be further developed for specific applications such as shipping and aviation.

Information on research funding in the field of fuels can be found on the BMWK's Energy Research website.

Electromobility

Electromobility is the key to climate-friendly mobility worldwide. The operation of electric vehicles using renewable electricity leads to significantly lower CO_2 emissions than combustion engines. Additionally, electric vehicles can be used as mobile energy storage units to balance out the fluctuating feed-in of wind and solar power into the grid and thereby support the expansion and market integration of renewable energy. The Federal Government supports the development of electric vehicles and their sales with a comprehensive package of measures which are continually being adapted. This includes the promotion of research and development, grants for the purchase and leasing of electric vehicles, expansion of the charging infrastructure as well as the public procurement of electric vehicles.

The coalition agreement stipulates that at least 15 million battery electric vehicles (BEVs) should be registered in Germany by 2030. In addition, one million public charging points are to be made available in the same period. Three measures are at the forefront of the promotion of electric mobility: temporary purchase incentives (environmental bonus), the expansion of the charging infrastructure and the promotion of the development of new value creation, such as battery cell production or support for the automotive industry during the transformation.

The environmental bonus is a central element of the package of measures. With the Environmental Bonus Directive, amended 1 January 2023, the Federal Government aims to promote the transi-

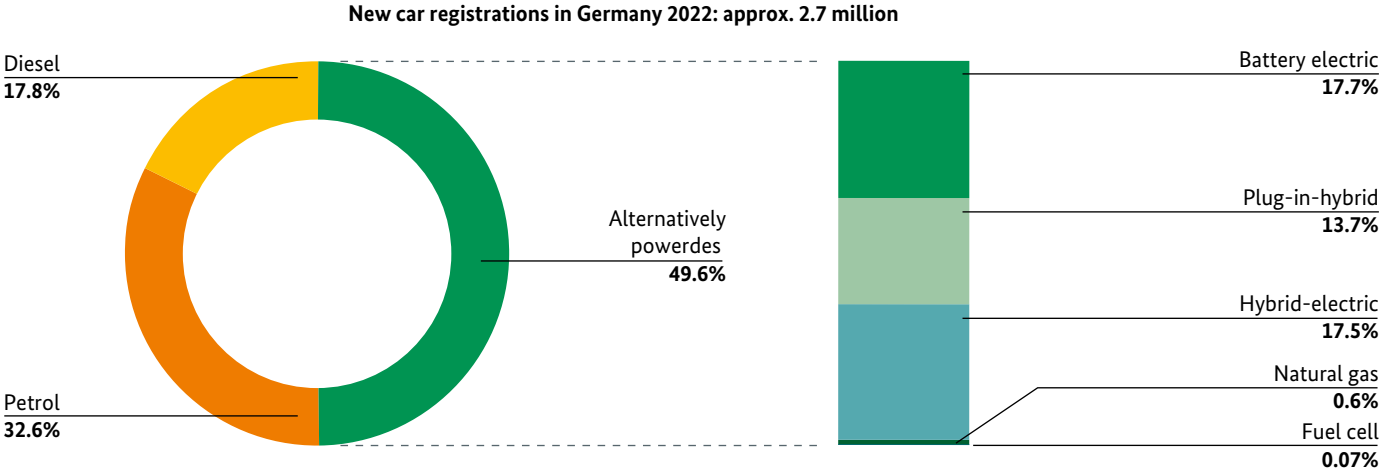
tion to clean mobility and enable the possibility of supporting the purchase and leasing of electric vehicles after 1 January 2023. At the same time, the subsidy for electric cars is degressive and has been revised so that it is only granted for vehicles with a proven positive impact on climate protection. Now, only purely electric vehicles are eligible for subsidies. The funding of plug-in hybrid vehicles has been discontinued. The application for funding can be submitted to the Federal Office for Economic Affairs and Export Control (in German only).

Since 1 January 2023, the federal part of the environmental bonus has been €4,500 up to a net list price of the base model of €40,000 and €3,000 for a net list price of €40,000 to €65,000. The minimum holding period for purchasing and leasing has doubled to 12 months.

As of 1 September 2023, only private persons will be eligible to apply. The federal share will fall further to €3,000 from 1 January 2024 and the upper limit for eligibility will drop from a €65,000 to €45,000 net list price of the base model.

In 2022, 1.3 million vehicles with alternative drive systems were registered. The number of new registrations for battery electric passenger cars (BEV) rose by around 32% to 470,559 vehicles (2021: 355,961), while the number of plug-in hybrids increased by 11.3% to 362,093 vehicles (2021: 325,449). The share of BEVs in total new car registrations rose to just under 18% (2021: 14%) and that of plug-in hybrids to around 14% (2021: 12%).

Figure 32: New car registrations in Germany, by fuel type, 2022



Source: Federal Motor Transport Authority (KBA) [24]

In total, around 1 million battery-electric vehicles (BEVs) and around 865,000 plug-in hybrids were registered in Germany by the end of 2022.

Table 26: New registration of electric cars in Germany

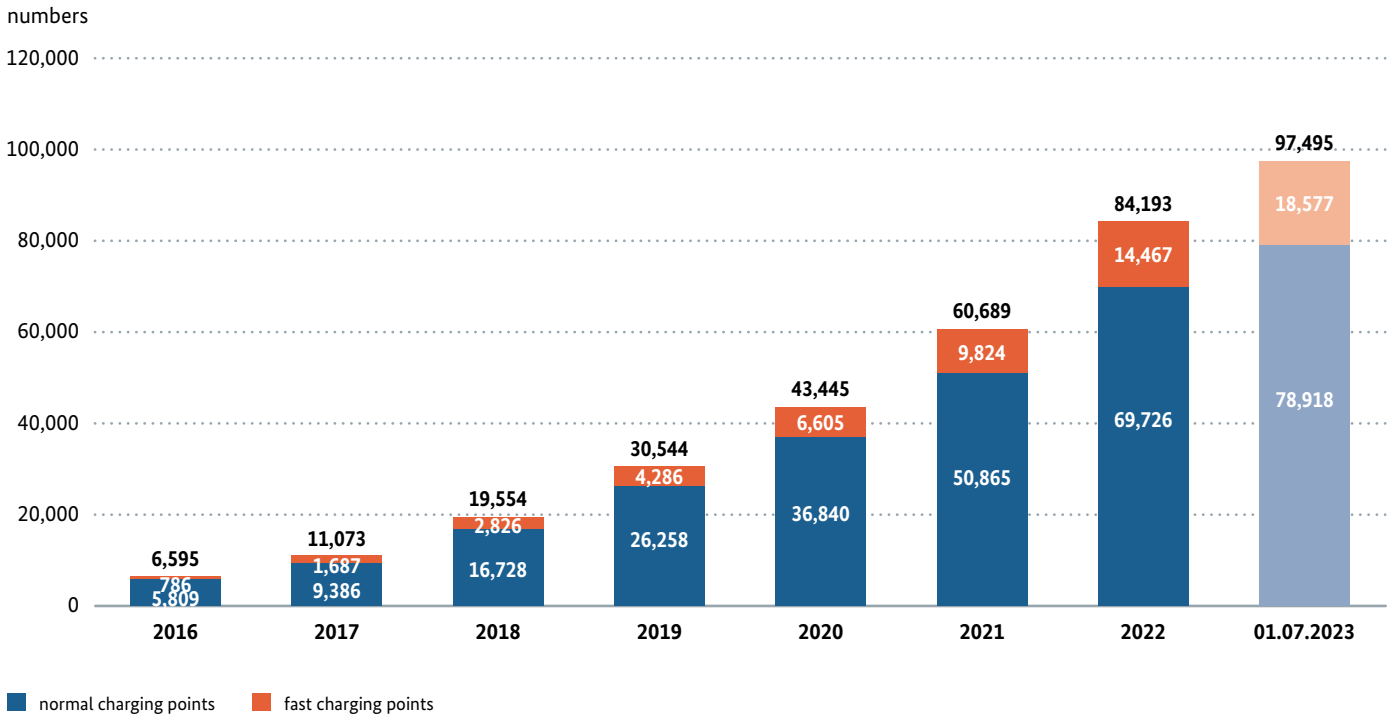
	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plug-in hybrid	–	–	–	–	–	20,975	44,419	66,997	102,175	279,861	565,956	864,712
Battery electric	4,541	7,114	12,156	18,948	25,502	34,022	53,861	83,175	136,617	309,083	618,460	1,013,009

Source: Federal Motor Transport Authority (KBA) [25]

Another central building block for strengthening demand for electromobility is the expansion of the charging infrastructure. The Federal Government's goal is to have one million public charging points available by 2030. The publicly accessible charging points in Germany reported under the Charging Station Ordinance (LSV) are published by the Federal Network Agency (in German only). By 1 July 2023, 78,918 normal charging points and 18,577 fast charging points had been registered with the Federal Network Agency. The largest share of around 61,800 charging points has a capacity of 15 to 22 kilowatts. With 20,522, the most charging points are installed in Bavaria, closely followed by North Rhine-Westphalia with 17,818 and Baden-Württemberg with 17,022 [26].

The amended Charging Station Ordinance (LSV) (in German only) came into force on 1 January 2022. This was an important step in advancing the demand-orientated and user-friendly expansion of the public charging infrastructure in Germany. A uniform, simple payment system is an important part. The amendment stipulates that in the future, contactless payment with standard credit and debit cards must be possible for ad hoc charging. This requirement applies to all publicly accessible charging stations that are put into operation after 1 July 2023. This deadline was extended in June 2023 to 1 July 2024.

Figure 33: Development of charging points in Germany from January 2016 – July 2023



Source: Federal Network Agency [26]

In addition to promoting electric vehicles, the Federal Government supports research and development through programmes that are technology-neutral and application-oriented.

In total, the Federal Government has provided around €3 billion for research and development since 2009. The various funding areas are divided between four Federal Ministries. An overview of funding opportunities is provided by the Federal Government's Funding Advisory Service, which acts as a central point of contact for companies and research institutions for questions relating to research funding.

The BMWK takes a holistic view of electromobility in its funding. All elements are considered. These include drive technology, battery research, energy

research, standardisation, strengthening of the value chain, networked cars, fleet and logistics concepts, digitalisation, grid integration and the intelligent billing of electricity at charging stations and infrastructure.

Promotion of research and development in the field of renewable energy

Research funding for the energy transition is an important building block for generation and consumption in Germany to become more climate-friendly, efficient and less dependent on energy imports. With its Energy Research Programme, the Federal Government supports climate protection targets while at the same time focusing on researching and developing efficiency potential, tapping into more domestic renewable energy sources and intelligently linking technologies as part of sector coupling.

The 7th Energy Research Programme has been operating since 2018 under the leadership of the BMWK and with the participation of the BMBF, BMEL and BMUV. The BMWK provides information on diverse research activities in the field of innovative energy technologies in the annual Federal Energy Research Report.

In 2022, the Federal Government invested €1.11 billion in project funding as part of the 7th Energy Research Programme. Around 7,365 ongoing research projects are supported by the Federal Government and 1,661 new projects have been approved. Around € 320 million have been channelled into institutional funding for Helmholtz Association research in the field of energy. Current data on project funding from the Federal Report on Energy Research is also published at EnArgus, the BMWK's central information system for energy research.

The BMWK provides support for application-oriented research and development, living labs for the energy transition and multilateral research cooperation. A central point here is the strengthening of technology and innovation transfer.

Four research projects in the field of renewable energy are presented below as examples.

One example from the **wind energy sector** is the joint project HiL-GridCoP – Hardware-in-the-Loop testing of the electrical grid compatibility of multi-megawatt wind-powered installations with high-speed generator systems:

Testing the grid compatibility of new types of wind turbines as part of the electrical certification process is still carried out exclusively in the field. Special load situations can only be tested at very high wind speeds, which sometimes makes the test lengthy and difficult to plan. As part of the HiL-GridCoP project, a new test is being set up and a test methodology developed to automate electrical certification in the laboratory. Thanks to weather-independent testing and the significantly reduced logistical effort, this process promises to safety check new turbine designs at reduced costs as well as allowing for shorter and more predictable time-to-market for new wind turbine types.

Another example is the joint **photovoltaic** project INNOMET – Development of innovative printing technologies for the fine-line metallisation of silicon solar cells:

In silicon solar cells, the front contacts are usually applied using a screen-printing process in which fine stainless-steel foils are used as a printing screen.

These films are to be replaced by thin glass films that are structured using lasers and which are expected to allow finer structures to be produced in screen-printing. Ultimately, the aim is to improve the quality of the printed solar cells and increase their efficiency.

Exemplary research projects in the field of **geothermal energy** are:

Joint project WaermeGut – Supporting the rollout of geothermal heat pumps for the heat transition through the nationwide, standardised provision of geo-information on near-surface geothermal energy (up to 400 m depth) in Germany.

The project serves to improve the geological database in order to support the rapid expansion of near-surface geothermal energy and thus contribute to the heat transition in Germany.

The data collected will be clearly evaluated with a traffic light tool developed for users and will be fed directly into the publicly accessible GeotIS geothermal information system of the Leibniz Institute for Applied Geophysics (LIAG).

Joint project Warm-Up – Geothermal energy for the heat transition: Accompanying the rollout of medium-depth geothermal energy (400 – 1000 m depth) in Germany.

The project supports exploration campaigns in the field of medium-depth geothermal energy. Possible geothermal sites are examined according to geological, technical, economic and social criteria, while considering improved framework conditions. In co-operation with the stakeholders, optimal development and utilisation concepts are to be developed at the locations, their economic consequences assessed and increased acceptance achieved. The aim is to enable project operators to initiate the practical realisation of geothermal projects at these locations.

The following table shows the number of new research projects approved by the BMWK and the funding allocated to them in the period from 2019 to 2022.

Table 27: Recently approved renewable energy projects

	2019		2020		2021		2022	
	number	grant in euros	number	grant in euros	number	grant in euros	number	grant in euros
Fuel cells	29	26,727,725	29	11,945,229	82	38,039,863	53	20,115,372
Digitization in the energy transition[1]	22	9,616,707	22	8,218,899	–	–	56	8,682,540
Energetic use of biogenic residues and waste[1]	69	16,958,848	38	7,725,907	47	11,054,758	59	10,444,833
Energy transition in transport	35	17,858,369	59	24,474,053	51	22,756,916	30	23,546,739
Energy transition and society	8	1,256,421	45	9,740,883	41	8,926,961	40	6,231,258
Buildings and quarters[1]	207	117,228,497	212	113,713,915	212	91,276,289	209	96,875,476
Geothermal[1]	25	24,096,905	41	40,950,841	25	19,473,012	27	25,507,849
Industry and commerce[1]	180	70,127,606	125	64,160,299	182	92,583,867	105	68,801,959
Photovoltaic	135	100,174,691	116	65,701,724	104	59,741,902	104	68,801,959
Sector link and hydrogen technologies[1]	4	2,266,862	52	65,050,008	50	22,373,373	97	24,701,511
Power grid	136	59,182,115	123	51,676,984	98	45,874,539	120	49,502,243
Energy storage	57	28,170,138	50	25,550,803	48	19,090,086	26	18,393,357
Technologies for the CO_2 circular economy	22	9,827,673	8	3,047,184	43	15,073,980	34	7,381,370
Energy system analysis and overarching questions of the energy transition	60	24,750,961	34	15,131,863	49	21,476,698	49	21,476,698
Thermal power plants[1]	74	31,294,856	83	38,301,151	74	39,123,836	86	31,923,354
There of solar thermal power plants (LPS EB%)			28	10,527,471				
Hydropower and ocean energy	7	3,540,994	–	–	–		3	314,473
Wind energy	112	78,993,941	99	65,323,153	84	43,901,836	97	89,192,379
Others*	–	–	–	–	0	–	–	–
Total	**1,182**	**622,073,309**	**1,137**	**621,240,366**	**1,190**	**550,767,915**	**1,190**	**571,893,369**

1 plus supplementary funding through the real laboratories of the energy transition programme

Source: BMWK

More information on the subject of energy research can be found on the BMWK website on Energy Research (in German only) and on the Internet portal of the Energy Research Networks.

Ongoing and completed research projects in the field of energy research are published by the BMWK on the EnArgus Internet portal on a daily basis.

In addition, information on funding topics and how to apply for research funding programmes in the field of renewable energy can be found on the website of the Jülich project management agency commissioned by the BMWK.

Data platforms of the Federal Network Agency

Core market data register – data for the energy transition

MaStR Marktstammdatenregister

The transformation of the German energy system can only take place in a targeted manner if the various stakeholders are able to draw on comprehensive, uniform and reliable data as a basis for decision-making. Efficient marketing of electricity and gas, restriction of new grid construction to the necessary extent and further development of the energy transition are challenges that can only be successfully met on the basis of reliable data.

The central objective of the core market data register (MaStR) is to simplify energy industry processes while significantly increasing data quality. This will reduce the bureaucratic burden on companies and citizens. The design of the new overall register has been regulated by the Core Market Data Register Ordinance (MaStRV) since 2017.

In the MaStR, all essential master data of the electricity and gas market is recorded and summarised in a central register. Most of the data is public, but personal data is explicitly protected. Public authorities can access the data. This allows them to either significantly simplify their own surveys or dispense with them altogether. Installation operators and other market players can use their MaStR numbers to refer to the data they have entered into the register. System operators must enter themselves and their systems in the register and are responsible for maintaining and curating their data. This also applies to all other market players and makes it possible to find electricity and gas system operators in the register. The list of those obliged to register includes electricity and gas suppliers, direct marketers and energy industry authorities, associations and institutions in the energy sector. A detailed description of those obliged to register can be found in the help section of the online platform of the core market data register.

The core market data register contains only core data: Names, addresses, locations, allocations, technologies, performance values, etc. It does not include so-called 'transaction data' connected to the energy activity of a market player or the processes within plants (e.g. production quantities, load flow data or storage levels). A detailed description of which data are recorded can also be found in the help section of the register.

The core market data register has been online for over 4 years. More than 95% of the installations are already registered. In addition to the scientific community, grid operators and politicians; the general public is also beginning to use the data more. The core data of the register make for a significant increase in data quality for many users. The Federal Network Agency regularly reports to the Federal Government on the status and progress of the core market data register (in German only).

The core market data register of the Federal Network Agency can be found with all background information at www.marktstammdatenregister.de (in German only).

SMARD – Electricity Market Data

The electricity market design is the foundation of the electricity supply. Supply meets demand, producers meet consumers. This is where the price and therefore the profitability of our electricity supply is decided.

SMARD has been using interactive graphics and near-real-time data to provide insight into the electricity market since 2017. How high are electricity supply and demand in Germany? What share comes from renewable energy sources? How does electricity consumption change throughout the day? How much electricity is imported and exported? How high is the wholesale electricity price in Germany compared to the average price in neighbouring countries?

Answers to these and many other questions are provided by the platform's market data. Another helpful feature is the ability to combine different data categories in one chart. The order of the building blocks can also be altered. A useful tool for answering many questions is to rearrange the layers of energy sources with just a few clicks.

The 'Germany at a glance' section provides power plant and market area views. In the power plant section, detailed information can be viewed, including generation by individual power stations with an installed generation capacity of 100 megawatts or more at the level of single power plant blocks and can also be obtained in the 'Download data' section. The market data visuals use a map to show the geographical electricity generation landscape in Germany. Further to this, other key figures such as electricity consumption and international wholesale prices are displayed.

With the download function, SMARD offers users the option of conveniently downloading time series of up to two years in one file in various formats and performing their own calculations. The Federal Network Agency makes the data available under the CC BY 4.0 licence. This means that they can be used and reproduced free of charge with reference to the source.

Clearly presented information

To ensure that everyone can understand the graphics, speak the same language and always have up-to-date information, the sections 'Electricity market explained', 'Current electricity market' and the SMARD ticker are also available.

Technical terms are clarified in the 'Electricity market explained' section. Articles about long-term developments in the electricity market appear regularly under 'Electricity market topics'.

The SMARD Ticker contains short articles with up-to-date information on special developments in the electricity market. For example, if there was a very high feed-in from renewables and this had an impact on various aspects of the market. The ticker also provides information about new platform functions.

The sections supplement the graphically displayed market data with helpful and up-to-date information prepared for a broad target group. In this way, SMARD contributes to transparency in the electricity market.

Part II: Renewable energy in the European Union

Recently, the European Union (EU) has taken far-reaching decisions in the area of climate and energy policy. The centrepiece of these is the 'European Green Deal' which was introduced by the EU Commission in December 2019. The Commission seeks with the Green Deal to create the transition to a modern, resource-efficient and competitive European economy that decouples its growth from resource consumption and achieves climate neutrality by 2050. An essential means of achieving this goal is to expand the use of renewable energy, whose share of the EU's total gross final energy consumption should more than double from around 22% today to 45% by 2030.

The ambitious promotion of the expansion of renewable energy at EU level dates back to 2009. With Directive 2009/28/EC (Renewable Energy Directive, RED), a binding framework for the EU-wide expansion of the use of renewable energy came into force for the first time, then aiming for a 20% share of gross final energy consumption by 2020. The target was exceeded with a share of 22.1%, although it should be noted that there was a sharp decline in total gross final energy consumption in the EU in 2020 due to the pandemic, which had a correspondingly positive effect on the share value. At the end of 2018, Directive (EU) 2018/2001 ('RED II') came into force as its successor, according to which Member States must by 2030 update their targets to ensure that the share of renewable energy sources in gross final energy consumption increase to at least 32% across the EU.

However, during the European energy crisis in 2022 resulting from the Russian war of aggression against Ukraine, it became clear that renewable energy sources must be expanded even more rapidly, not only for reasons of climate protection, but also to increase energy security. Consequently, on 16 June 2023, the Member States agreed to a comprehensive revision of RED II, which raises the European target for the share of renewable energy sources in gross final energy consumption to 42.5 – 45% by 2030.

This means that the expansion originally planned under RED-II should be roughly doubled by 2030. The specific targets of RED-II are divided into binding targets, which if not met can also result in infringement proceedings and more far-reaching indicative targets, which are not binding. Thus, of the overall renewables target, 42.5% must be achieved by the Member States. The additional, indicative target of a further 2.5% is to be met through voluntary measures taken by Member States or through pan-European measures. To realise the target, wind energy and photovoltaic systems with an annual capacity of more than 100 gigawatts will have to be installed in the EU-27 by 2030. RED-II thereby reinforces the greatly increased German expansion targets and at the same time makes them binding. Parallel to this, the new EU targets form a framework for further-reaching measures and goals such as the EU solar strategy, which aims to roughly triple photovoltaic capacity to 600 gigawatts by 2030.

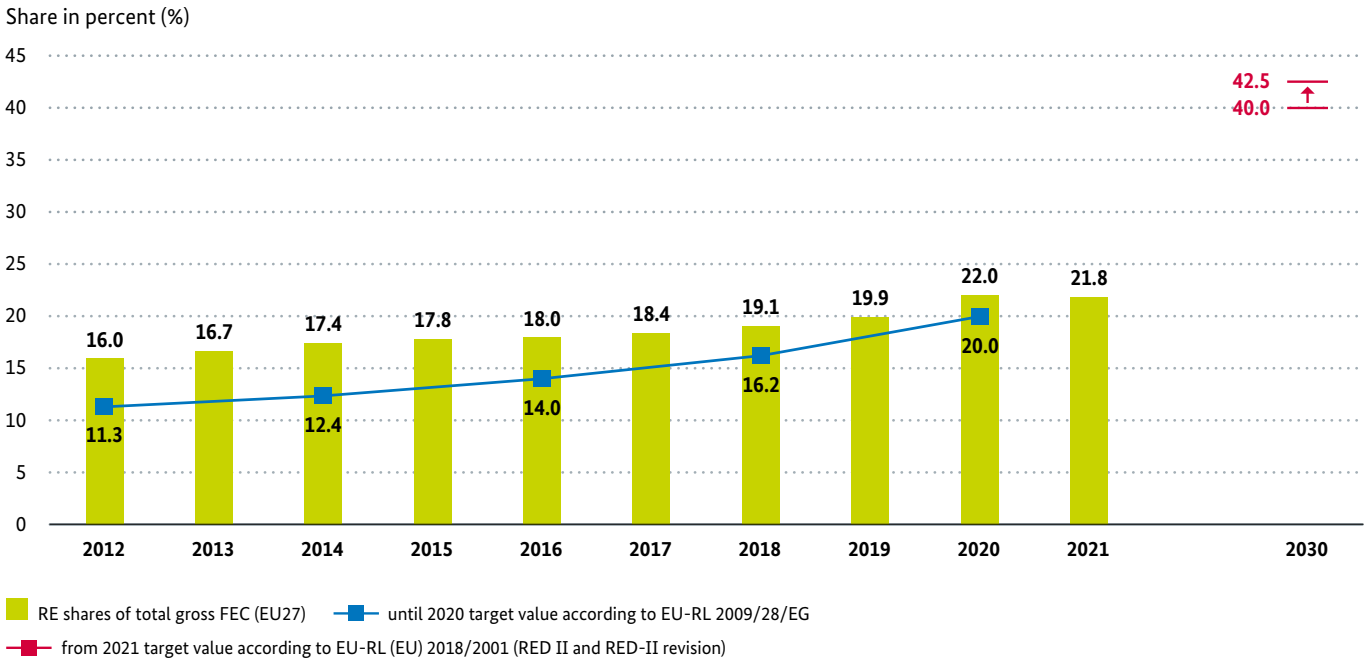
The revision of RED-II introduces sector targets for 2030 in addition to the overall goal. In the heating sector, the share of renewable energy sources must increase by 0.8 percentage points annually between 2021 and 2025 and by 1.1 percentage points as from 2026. This is supplemented by the indicative target which aims to cover 49% of heating requirements for buildings with renewable energy sources by 2030. In the transport sector, the binding target will be raised from 14% to a 29% share of renewable energy sources by 2030. Most of this is likely to result from the expansion of electromobility. A new binding sub-target of 5.5% relates to the use of advanced biofuels and electricity-based fuels, with 1% to be accounted for by hydrogen and e-fuels. The indicative target for the industrial sector is to increase the share of renewables in total energy consumption by 1.6 percentage points per year. By 2030, 42% of the hydrogen used must come from renewable energy sources, and 60% by 2035. For Germany, this means a demand of 41 to 83 terawatt-hours of green hydrogen, depending on the scenario.

Another important component of the RED-II revision is the continuation of most current regulations for accelerating authorisation procedures under the EU Emergency Ordinance. This means that in priority areas, complex assessment steps at project level can be dispensed with if they have already taken place at the planning level.

The revision of RED-II is part of the 'Fit for 55' package, a set of measures to achieve the EU-27's climate targets. 'Fit for 55' refers to the EU's climate target of reducing greenhouse gas emissions by 55% by 2030. This goal is legally anchored in the European Climate Law, which came into force in June 2021. It also includes the goal of climate neutrality in the EU by 2050. Another framework for RED-II is the so-called Governance Regulation, which created a governance system for the EU's Energy and Climate Union. This is the legal framework for the measures designed to ensure that the EU's energy and climate targets are met by 2030 and beyond. The system includes planning and reporting obligations of the Member States as well

as monitoring powers and obligations of the EU Commission. Each EU Member State was required to submit an integrated National Energy and Climate Plan (NECP) for the next decade (2021 – 2030) by 2020. In the NECPs, Member States describe their national energy and climate policy targets, strategies and measures as well as formulate their national target contributions to the EU 2030 targets. In view of the increased targets, Member States should submit updated NECPs to the Commission by mid-2024.

Figure 34: Shares of renewable energy in gross final energy consumption in the EU (until 2020 according to EU Directive 2009/28/EC, from 2021 according to EU Directive (EU) 2018/2001) and targets from the Directive on energy from renewable sources (RED, RED II and revision of RED-II)



Source: Eurostat (NRG_IND_REN) [27]

Notes:

The data on the generation and use of renewable energy sources in Germany provided in European and international statistics differ in part from the data provided by German sources. In addition to the different origin of the data, different accounting methods also play a role.

In the 'Europe' section, the data for Germany is taken from the international statistics for reasons of consistency. However, the more detailed data from the national sources on the preceding pages are generally more reliable.

The withdrawal of the United Kingdom from the EU on 1 January 2021 is also associated with changes in the statistics on the use of renewable energies in the EU. Therefore, since 2021, the presentation has been of the EU-27 excluding the United Kingdom. Comparability with the data in the previous brochures is therefore only possible to a limited extent for the EU section.

Table 28: Shares of renewable energy in total gross final energy consumption and gross final energy consumption for electricity

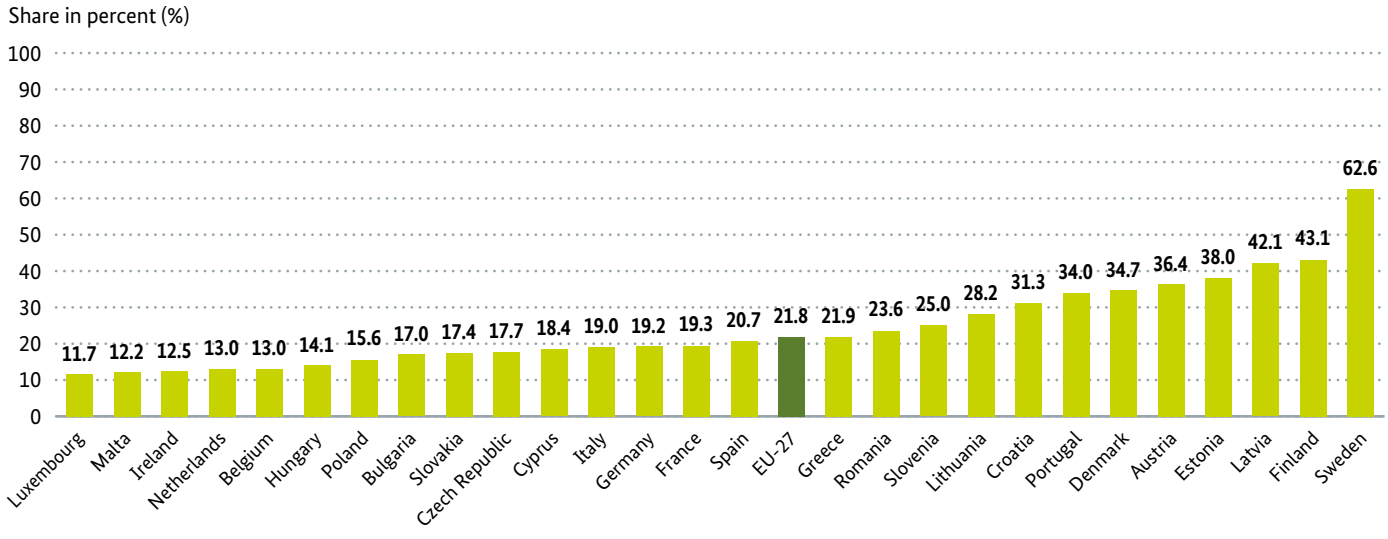
	RE shares of gross final energy consumption (%)					RE shares of gross final energy consumption for electricity[1] (%)				
	2005	2010	2015	2020	2021	2005	2010	2015	2020	2021
Austria	24.4	31.2	33.5	36.5	36.4	62.9	66.4	71.5	78.2	76.2
Belgium	2.3	6.0	8.1	13.0	13.0	2.4	7.2	15.6	25.1	26.0
Bulgaria	9.2	13.9	18.3	23.3	17.0	8.7	12.4	19.0	23.6	18.8
Croatia	23.7	25.1	29.0	31.0	31.3	35.2	37.5	45.4	53.8	53.5
Cyprus	3.1	6.2	9.9	16.9	18.4	0.0	1.4	8.4	12.0	14.8
Czech Republic	7.1	10.5	15.1	17.3	17.7	3.8	7.5	14.1	14.8	14.5
Denmark	16.0	21.9	30.5	31.7	34.7	24.6	32.7	51.3	65.3	62.6
Estonia	17.5	24.6	29.0	30.1	38.0	1.1	10.3	16.2	28.3	29.3
Finland	28.8	32.2	39.2	43.9	43.1	26.9	27.7	32.2	39.6	39.5
France	9.3	12.7	14.8	19.1	19.3	13.7	14.8	18.8	24.8	25.0
Germany	7.2	11.7	14.9	19.1	19.2	10.6	18.2	30.9	44.2	43.7
Greece	7.3	10.1	15.7	21.7	21.9	8.2	12.3	22.1	35.9	35.9
Hungary	6.9	12.7	14.5	13.9	14.1	4.4	7.1	7.3	11.9	13.7
Ireland	2.8	5.8	9.1	16.2	12.5	7.2	15.6	25.7	39.1	36.4
Italy	7.5	13.0	17.5	20.4	19.0	16.3	20.1	33.5	38.1	36.0
Latvia	32.3	30.4	37.5	42.1	42.1	43.0	42.1	52.2	53.4	51.4
Lithuania	16.8	19.6	25.7	26.8	28.2	3.8	7.4	15.5	20.2	21.3
Luxembourg	1.4	2.9	5.0	11.7	11.7	3.2	3.8	6.2	13.9	14.2
Malta	0.1	1.0	5.1	10.7	12.2	0.0	0.0	4.3	9.5	9.7
Netherlands	2.5	3.9	5.7	14.0	13.0	6.3	9.6	11.0	26.4	30.4
Poland	6.9	9.3	11.9	16.1	15.6	2.7	6.6	13.4	16.2	17.2
Portugal	19.5	24.1	30.5	34.0	34.0	27.7	40.6	52.6	58.0	58.4
Romania	17.6	22.8	24.8	24.5	23.6	28.8	30.4	43.2	43.4	42.5
Slovakia	6.4	9.1	12.9	17.3	17.4	15.7	17.8	22.7	23.1	22.4
Slovenia	19.8	21.1	22.9	25.0	25.0	28.7	32.2	32.7	35.1	35.0
Spain	8.4	13.8	16.2	21.2	20.7	19.1	29.8	37.0	42.9	46.0
Sweden	40.0	46.1	52.2	60.1	62.6	50.9	55.8	65.7	74.5	75.7
Region EU-27	**10.2**	**14.4**	**17.8**	**22.0**	**21.8**	**16.4**	**21.3**	**29.7**	**37.4**	**37.5**

For details on the method used to calculate these shares, see the 'Information on methodology' section.

1 In order to determine the shares of renewable energy in gross electricity consumption, electricity production from wind and hydropower was calculated using the normalisation rule defined in the EU Directive.

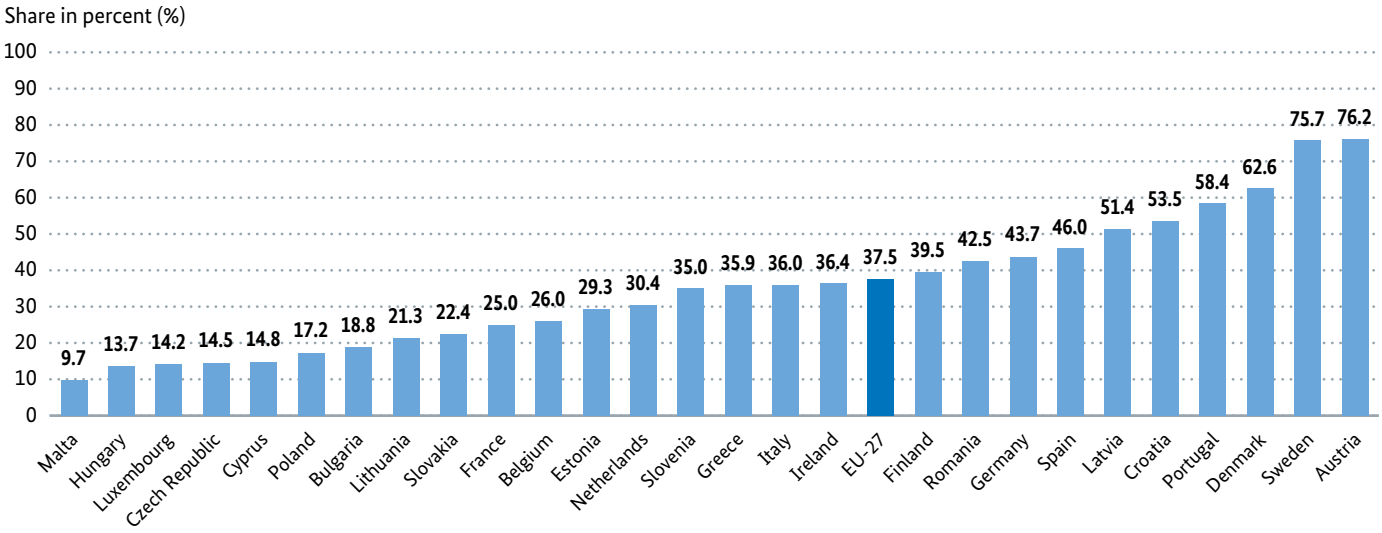
Source: Eurostat (NRG_IND_REN) [27]

Figure 35: Shares of renewable energy in total gross final energy consumption in the EU, 2021



Source: Eurostat (NRG_IND_REN) [27]

Figure 36: Shares of renewable energy in gross final energy consumption for electricity in the EU, 2021



Source: Eurostat (NRG_IND_REN) [27]

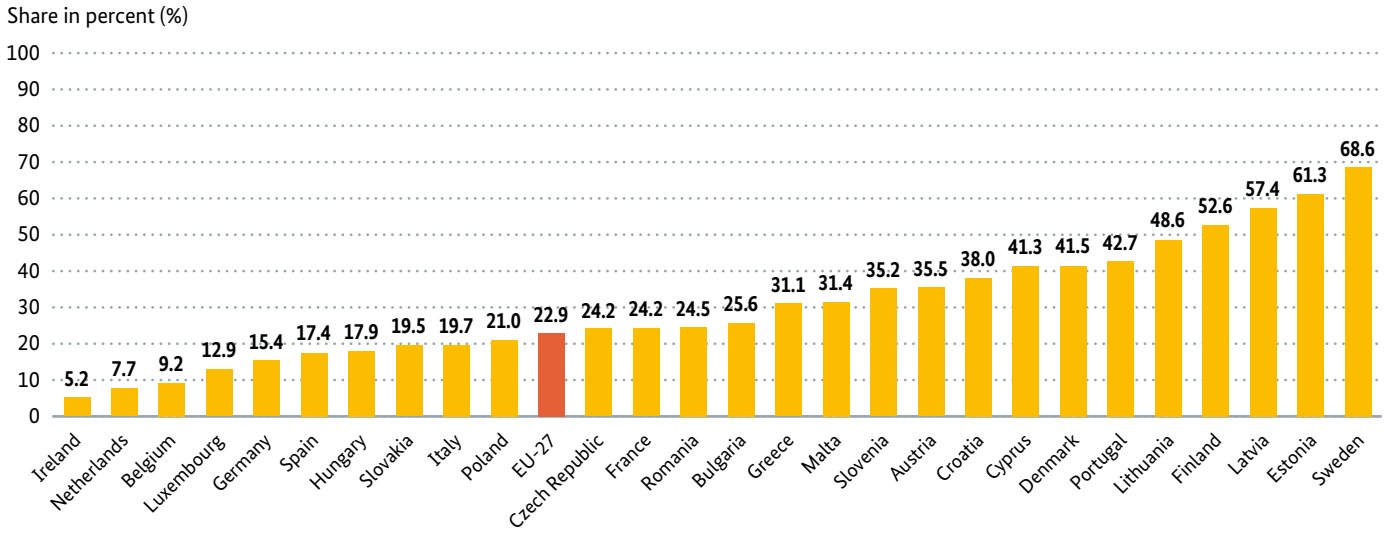
Table 29: Shares of renewable energy in gross final energy consumption for heating and cooling and in final energy consumption in transport

	Renewable energy shares of gross final energy consumption in the heating/cooling sector (%)					RE shares of gross FEC for transport (%)				
	2005	2010	2015	2020	2021	2005	2010	2015	2020	2021
Austria	22.8	31.0	33.2	35.0	35.5	5.1	10.7	11.4	10.3	9.4
Belgium	3.4	6.7	7.9	8.4	9.2	0.7	4.8	3.9	11.0	10.3
Bulgaria	14.3	24.3	28.9	37.2	25.6	0.9	1.5	6.5	9.1	7.6
Croatia	30.0	32.9	38.6	36.9	38.0	1.0	1.1	2.4	6.6	7.0
Cyprus	10.0	18.8	24.1	37.1	41.3	0.0	2.0	2.5	7.4	7.2
Czech Republic	10.8	14.1	19.8	23.5	24.2	1.1	5.2	6.5	9.4	7.5
Denmark	22.6	30.4	39.5	51.1	41.5	0.4	1.1	6.4	9.7	10.5
Estonia	32.4	43.2	50.0	58.8	61.3	0.2	0.4	0.4	12.2	11.2
Finland	39.1	44.0	52.6	57.6	52.6	0.9	4.4	24.6	14.3	20.5
France	12.4	16.2	18.9	23.4	24.2	0.8	6.6	8.4	9.2	8.2
Germany	7.7	12.1	13.4	14.5	15.4	4.0	6.4	6.6	10.0	8.0
Greece	13.4	18.7	26.6	31.9	31.1	0.1	1.9	1.1	5.3	4.3
Hungary	9.9	18.1	21.3	17.7	17.9	1.0	6.2	7.2	11.6	6.2
Ireland	3.4	4.3	6.2	6.3	5.2	0.1	2.5	5.9	10.2	4.3
Italy	8.2	15.6	19.3	19.9	19.7	1.0	4.9	6.5	10.7	10.0
Latvia	42.7	40.7	51.7	57.1	57.4	2.4	4.0	3.6	6.7	6.4
Lithuania	29.3	32.5	46.1	50.4	48.6	0.7	3.8	4.6	5.5	6.5
Luxembourg	3.6	4.7	6.9	12.6	12.9	0.2	2.1	6.7	12.6	8.0
Malta	1.0	7.3	14.6	23.0	31.4	0.0	0.0	4.7	10.6	10.6
Netherlands	2.4	3.1	5.3	8.1	7.7	0.5	3.4	5.6	12.6	9.0
Poland	10.2	11.8	14.8	22.1	21.0	1.7	6.6	5.7	6.6	5.7
Portugal	32.1	33.8	40.1	41.5	42.7	0.5	5.5	7.4	9.7	8.6
Romania	17.9	27.2	25.9	25.3	24.5	1.9	1.4	5.5	8.5	7.7
Slovakia	5.0	7.9	10.8	19.4	19.5	1.7	5.3	8.6	9.3	8.8
Slovenia	26.4	29.5	36.2	32.1	35.2	0.8	3.1	2.2	10.9	10.6
Spain	9.4	12.5	16.9	18.0	17.4	1.3	5.0	1.1	9.5	9.2
Sweden	49.0	57.1	63.2	66.4	68.6	6.6	9.6	21.5	31.9	30.4
Region EU-27	**12.4**	**17.0**	**20.3**	**23.0**	**22.9**	**1.8**	**5.5**	**6.8**	**10.3**	**9.1**

For further information on the calculation of the shares, see also the section 'Methodological notes'.

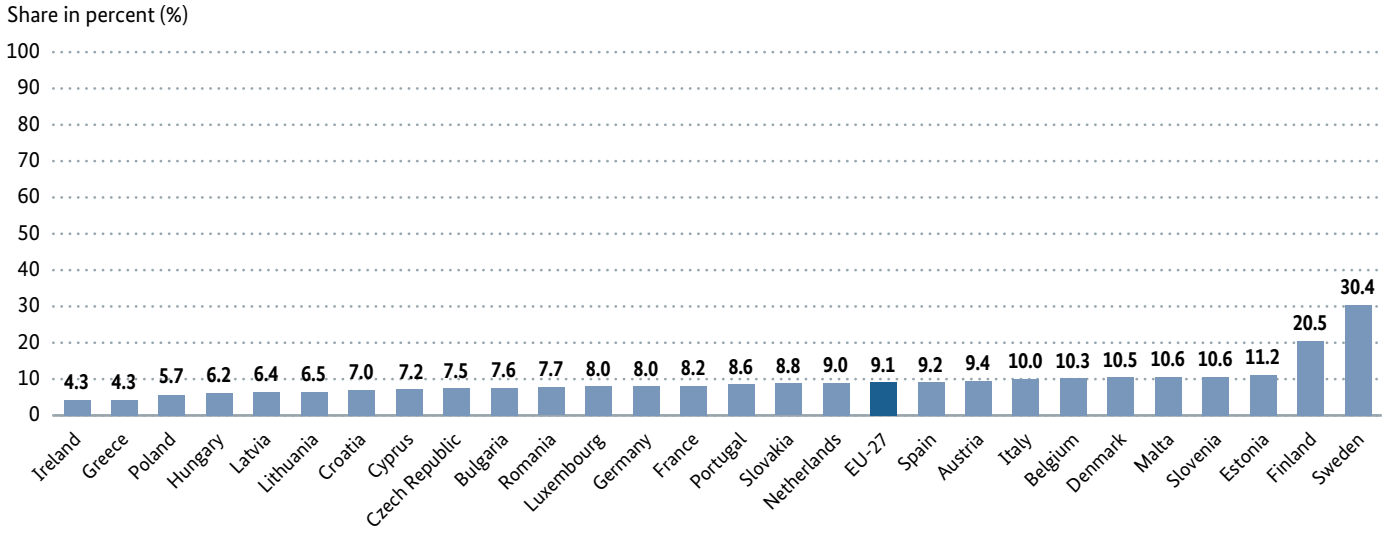
Source: Eurostat (NRG_IND_REN) [27]

Figure 37: Shares of renewable energy in gross final energy consumption for heating and cooling in the EU, 2021



Source: Eurostat (NRG_IND_REN) [27]

Figure 38: Shares of renewable energy in cooling and in final energy consumption in transport in the EU, 2021



Source: Eurostat (NRG_IND_REN) [27]

Estimate of the shares of renewable energy in Germany in 2022 according to EU Directive

Initial calculations and estimations based on the EU's calculation methodology (EU Directive 2018/2001, RED II) indicate that renewable energy sources in Germany reached a share of 20.8% of gross final energy consumption (BEEV) in 2022 and therefore almost one and a half percentage points more than in the previous year (2021: 19.4%).

Table 30: Shares of renewable energy in total gross final energy consumption (GFEC) and in electricity, heat and transport in Germany

Calculated according to the EU Directive

	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022[1]
	(%)													
RES share in GFEC electricity	16.4	21.3	23.3	25.1	26.8	28.6	29.7	30.2	31.1	32.1	34.1	37.4	37.5	
RES share in GFEC heating/cooling	12.4	17.0	17.4	18.6	19.0	19.9	20.3	20.4	20.8	21.6	22.4	23.0	22.9	
RES share in GFEC transport	1.8	5.5	4.1	5.8	6.1	6.6	6.8	7.2	7.5	8.3	8.8	10.3	9.1	
RES share in total GFEC	**7.2**	**11.7**	**12.5**	**13.5**	**13.8**	**14.4**	**14.9**	**14.9**	**15.5**	**16.7**	**17.3**	**19.1**	**19.4**	**20.8**

1 This overview reflects the current status of available statistics. For 2022, only provisional figures were available at the editorial deadline. Values up to 2020 calculated according to EU-RL 2009/28/EG, from 2021 according to EU-RL (EU) 2018/2001 (RED II and revision of RED II).

Source: EUROSTAT (SDG_07_40) [27]

Renewables-based electricity generation in the EU

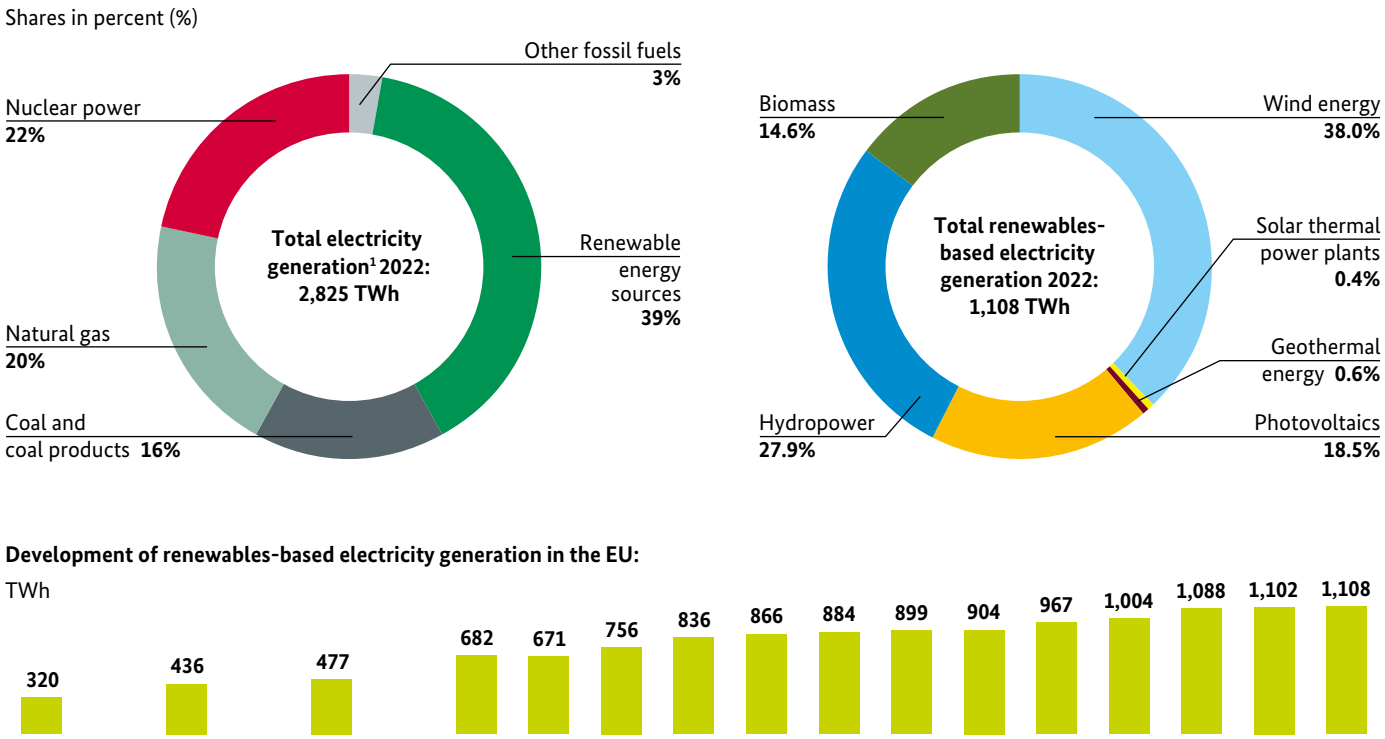
The National Action Plans, which the Member States were required to submit within the framework of Directive 2009/28/EC, showed that there would have to be a significant focus on the expansion of renewable energy across the EU. As a result, the share of renewable energy sources in the EU-27's electricity consumption more than doubled between 2005 and 2020, from 16.4% to 37.4%. And as before, both across the EU and in Germany, the expansion of renewable energy in the electricity sector is progressing much faster than in the heating and transport sectors.

Complete share values are available up to and including 2021. Across the EU, renewable energy sources accounted for 37.5% of gross electricity consumption. However, shares vary greatly across Member States. While Austria (76.2%), Sweden (74.5%) and Denmark (65.3%) had the highest percentages; Malta (9.5%), Luxembourg (13.5%) and Poland (16.2%) had the lowest.

In 2022, total gross electricity generation from renewable energy sources increased only slightly to 1,108 terawatt-hours (2021: 1,102 terawatt-hours) despite a significant increase in electricity generation from wind energy and photovoltaics. This was due to the year's extreme drought which caused electricity generation from hydropower to fall by almost 18% to 308.6 terawatt-hours (2021: 374.8 terawatt-hours).

After replacing hydropower as the most important source of renewable energy in the EU-27 for the first time in 2019, wind energy accounted for 38% of all electricity generated from renewable energy in 2022 (2021: 35.1%). Hydropower accounted for 27.8%, photovoltaics for 18.5% and biomass for 14.6%.

Figure 39: Electricity generation in the EU-27, 2022



Other = industrial waste, non-renewable municipal waste, pumped storage, etc.
Marine energy is not shown due to the small quantities involved.

1 does not include net imports

Sources: EUROSTAT (NRG_IND_PEHCF und NRG_IND_PEHNF) [28], [29]

Table 31: Electricity generation from renewable energy sources in the EU-27

	2010	2015	2016	2017	2018	2019	2020	2021	2022
	(TWh)								
Biomass[1]	111.6	149.4	151.1	153.6	155.5	159.7	162.6	169.4	161.5
Hydropower[2]	401.3	363.2	372.7	322.5	370.2	345.6	375.5	374.8	308.6
Wind energy	139.8	263.2	266.8	312.3	320.6	367.1	397.8	386.9	421.3
Geoth. energy	5.6	6.6	6.7	6.7	6.7	6.7	6.7	6.5	6.4
Photovoltaics	22.5	95.3	95.5	102.1	108.2	118.2	140.1	158.6	205.1
Solar thermal	0.8	5.6	5.6	5.9	4.9	5.7	5.0	5.2	4.5
Ocean energy	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
RE total	682.0	883.8	898.9	903.6	966.6	1,003.6	1,088.3	1,101.9	1,108.0
RE share of gross electricity consumption[3]	**22.9%**	**30.5%**	**30.8%**	**30.6%**	**32.8%**	**34.5%**	**38.9%**	**37.8%**	**39.0%**
EU-gross final electricity generation	2,979.7	2,900.6	2,922.0	2,954.5	2,938.0	2,902.4	2,784.9	2,906.5	2,825.4
Import	291.5	387.6	362.5	366.6	372.3	369.4	381.0	401.4	420.6
Export	286.6	394.3	361.9	371.1	363.5	366.5	367.0	394.1	407.6

1 Including biogas, sewage gas and landfill gas, liquid and solid biogenic fuels and the renewable share of municipal waste

2 In the case of pumped storage power plants, power generation from natural inflow only

3 Gross electricity consumption = gross electricity generation plus imports minus exports; not calculated using rules in EU Directive.

This overview reflects the current status of available statistics (until 2021) EUROSTAT (generation of electricity and derived heat by fuel), 2022 EUROSTAT (gross generation of electricity and derived heat by non-combustible and combustible energy sources by plant type and producer type).

Sources: EUROSTAT (NRG_IND_PEHCF und NRG_IND_PEHNF) [28], [29], [30], [31]

Table 32: Electricity generation from renewable energy sources in the EU-27, 2022

	Hydro-power[1]	Wind energy	Solid biomass[2]	Biogas[3]	Liquid biogenic fuels	Photo-voltaics	Solar thermal power plants	Geo-thermal energy	Ocean energy	Total
	(TWh)									
Austria	39.2	7.2	4.1	0.6	0.0001	3.8	-	< 0,000	-	54.9
Belgium	1.6	12.0	3.4	1.0	0.1	7.1	-	-	-	25.1
Bulgaria	3.8	1.5	2.1	0.2	-	1.9	-	-	-	9.4
Croatia	6.2	2.1	0.7	0.4	-	0.2	-	0.1	-	9.7
Cyprus	-	0.2	-	0.1	-	0.6	-	-	-	0.9
Czech Republic	3.1	0.6	2.8	2.6	-	2.6	-	-	-	11.7
Denmark	0.02	19.0	6.7	0.6	-	2.2	-	-	-	28.5
Estonia	0.02	0.7	1.6	0.0	-	0.6	-	-	-	2.8
Finland	13.5	12.0	12.2	0.3	0.001	0.4	-	-	-	38.4
France	51.1	38.1	7.0	3.2	0.01	20.6	-	0.1	0.5	120.5
Germany	23.6	125.3	16.8	30.2	0.2	60.8	-	0.2	-	257.1
Greece	4.6	10.9	0.0	0.2	-	7.0	-	-	-	22.7
Hungary	0.2	0.6	1.8	0.3	-	4.7	-	< 0,000	-	7.6
Ireland	1.0	11.2	0.9	0.2	-	0.1	-	-	-	13.3
Italy	30.1	20.6	6.6	7.7	3.1	28.1	-	5.8	-	102.0
Latvia	2.7	0.2	0.6	0.2	-	0.0	-	-	-	3.8
Lithuania	1.0	1.5	0.6	0.2	-	0.3	-	-	-	3.6
Luxembourg	1.1	0.3	0.3	0.0	-	0.2	-	-	-	2.0
Malta	-	0.0	-	0.0	-	0.3	-	-	-	0.3
Netherlands	0.0	21.6	8.9	0.8	-	16.8	-	-	-	48.2
Poland	3.0	19.5	5.9	1.3	0.001	8.1	-	-	-	37.8
Portugal	8.8	13.3	3.8	0.3	-	3.5	-	0.2	-	29.8
Romania	14.3	7.0	0.5	-	-	1.8	-	-	-	23.6
Slovakia	3.8	0.0	1.0	0.4	-	0.7	-	-	-	5.9
Slovenia	22.1	62.8	5.8	1.0	0.01	30.2	4.5	-	0.02	126.4
Spain	3.4	0.0	0.1	0.1	-	0.6	-	-	-	4.3
Sweden	70.3	33.1	11.8	0.0	0.3	2.0	-	-	-	117.5
EU 27	**308.6**	**421.3**	**105.9**	**52.0**	**3.7**	**205.1**	**4.5**	**6.4**	**0.5**	**1,108.0**

This overview is based on currently available statistics (see source). The data may differ from national statistics due to different methodologies used or other factors.
All data are provisional; discrepancies in the totals due to rounding.

1 In the case of pumped storage power plants, power generation from natural inflow only

2 Including the biogenic share of municipal waste

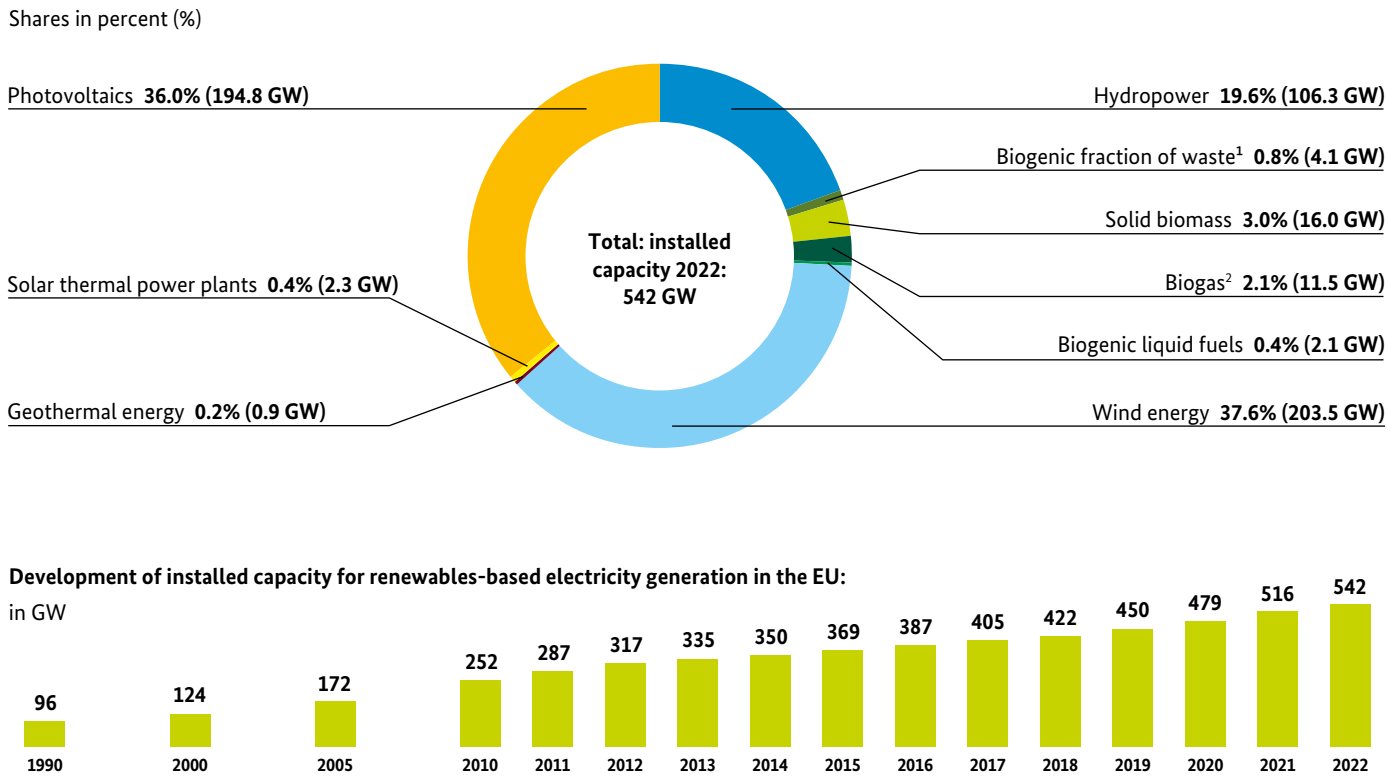
3 Including sewage and landfill gass

Source: EUROSTAT (NRG_IND_PEHCF und NRG_IND_PEHNF) [28], [29]

As in previous years, Germany made the largest contribution to total gross electricity generation among the Member States of the EU-27 in 2022 with 257.1 terawatt-hours or 23.2%. Spain followed with 126.4 terawatt-hours, France with 120.5 terawatt-hours, Sweden with 117.5 terawatt-hours and Italy with 102 terawatt-hours.

In the course of the current expansion of renewable energy, installed capacity is increasing faster than electricity generation. This is because wind and solar technologies have lower full-load hours than hydropower plants, which until a few years ago still dominated the stock of renewable energy generation capacity. Thus, the installed capacity of renewable energy sources in the EU-27 rose by a factor of 3.2 from 172 gigawatts in 2005 to 542 gigawatts at the end of 2022, while electricity generation rose by a factor of only 2.3 from 477 terawatt-hours to 1,108 terawatt-hours. While hydropower still dominated in 2005 with two-thirds of the installed capacity at that time, wind energy was already clearly in the lead at the end of 2021 with almost 37% of installed capacity, followed by photovoltaics with 31%. Hydropower, on the other hand, was only in third place with a good 25%.

Figure 40: Total installed renewables-based electricity generation capacity in the EU-27, 2022



1 Biogenic share of waste in waste incineration plants estimated at 50%

2 Including landfill gas and sewage gas

Source: Eurostat ([nrg_inf_epcrw]) [32]; IRENA ("Renewable Capacity Statistics 2023") [33]

Wind energy use

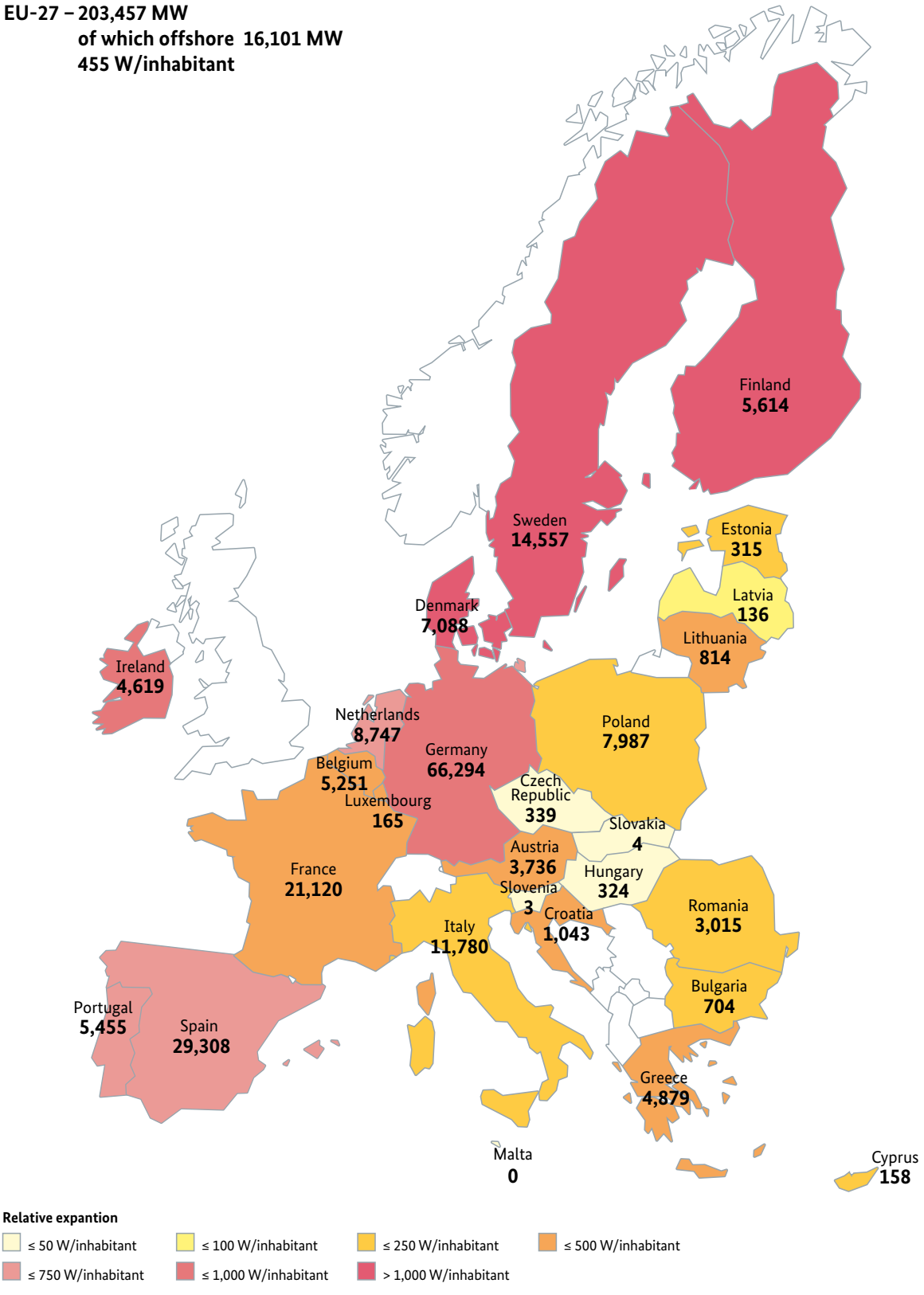
The expansion of wind energy use in the EU-27 accelerated significantly in 2022. With an addition of a good 14 gigawatts, almost a third more onshore wind energy capacity was installed than in the previous year (2021: 10.7 gigawatts) and more than in any year before. As in the previous year, Sweden added the most onshore wind energy capacity with just under 2.5 gigawatts. Finland followed close behind with an expansion of just under 2.4 gigawatts. With a good 2.1 gigawatts, Germany was in 3rd place in terms of new installations, followed by France with 1.9 gigawatts. After a weak previous year, offshore installations also increased significantly. At a good 1.6 gigawatts, around two and a half times as much new capacity was connected to the grid as in the previous year (0.6 gigawatts). Nevertheless, the expansion figure was still a third below the previous record set in 2020 (just under 2.5 gigawatts). With 760 megawatts of new offshore capacity, the Netherlands installed the most. It was followed by France with 480 megawatts and Germany with 355 megawatts.

This means that a total wind energy capacity of 204 gigawatts was installed in the EU-27 at the end of 2022 of which 187.3 gigawatts was on land and 16.7 gigawatts offshore. With 66.3 gigawatts, which corresponds to around a third of all European wind energy capacity, Germany was still well ahead of Spain (29.3 gigawatts), France (21.1 gigawatts), Sweden (14.6 gigawatts) and Italy (11.8 gigawatts).

If the installed wind energy capacity is viewed relative to the population of the individual Member States of the EU-27, a different picture emerges: EU-wide, a capacity of 456 watts per inhabitant was installed at the end of 2022, almost 9% more than in the previous year (2021: 419 watts per inhabitant). Due to its strong expansion, Sweden was ahead for the first time with 1,410 watts per inhabitant. Denmark, which had previously led this statistic, followed with 1,216 and then Finland with 1,016, Ireland with 930 and Germany with 797 watts per inhabitant.

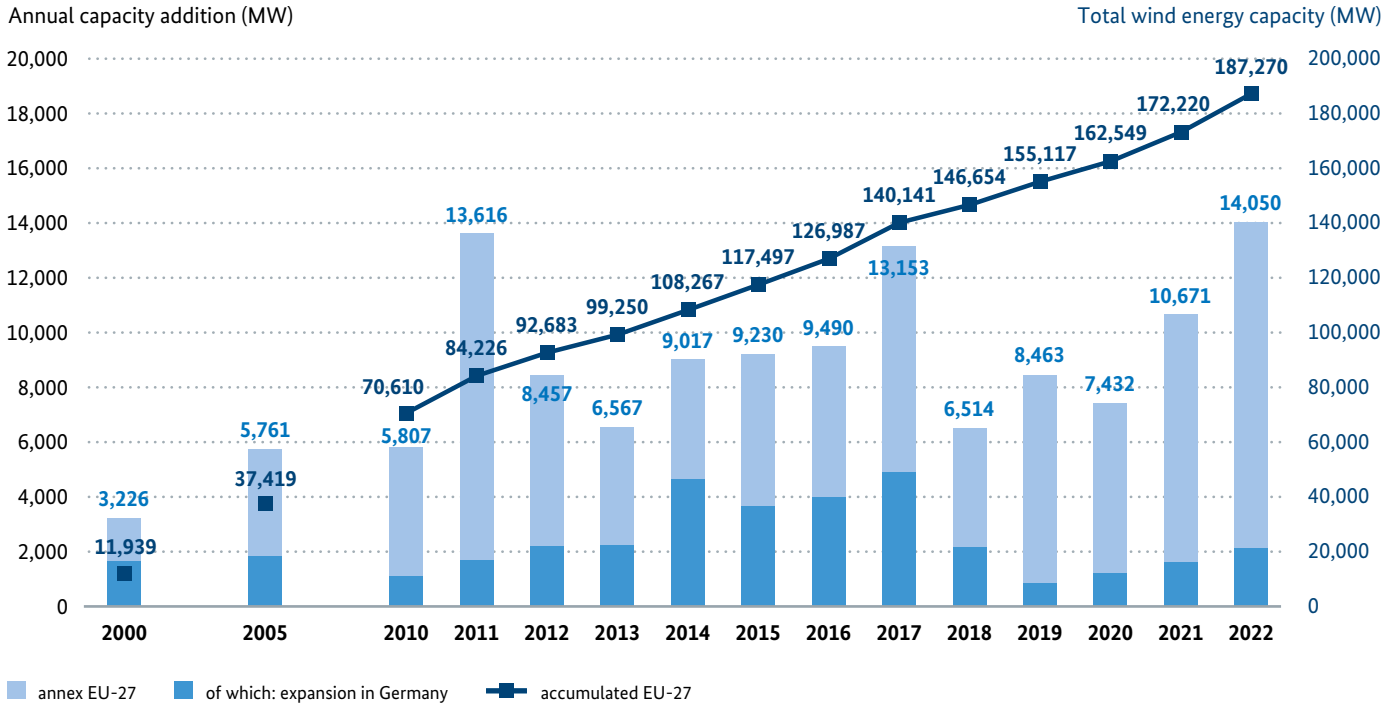
In 2022, all wind turbines installed in the EU-27 together produced 421.3 terawatt-hours of electricity, almost 9% more than in the previous year (2021: 386.9 terawatt-hours). EU-wide, wind energy thus covered 14.9% of electricity consumption (2021: 13.3%) [33].

Figure 41: Total installed wind energy capacity in the EU-27 at the end of 2022



Source: IRENA ("Renewable Capacity Statistics 2023") [33]

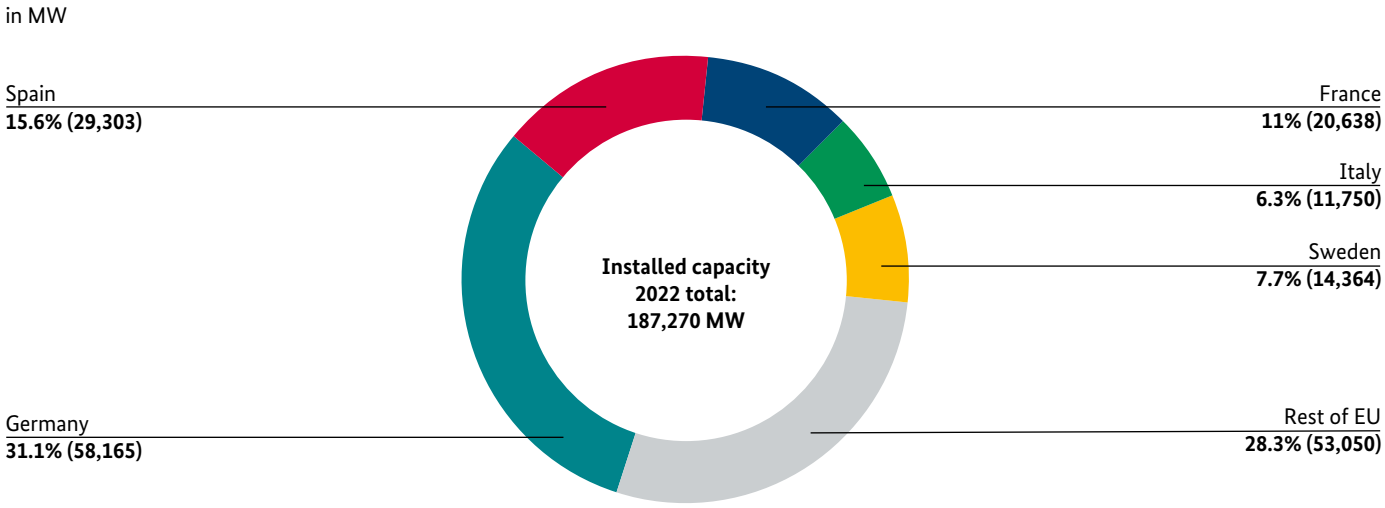
Figure 42: Wind energy onshore: Development of total wind energy output (in MW) in the EU-27



The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2022')

Source: Eurostat (nrg_inf_epcrw)[32]; IRENA ("Renewable Capacity Statistics 2023") [33]

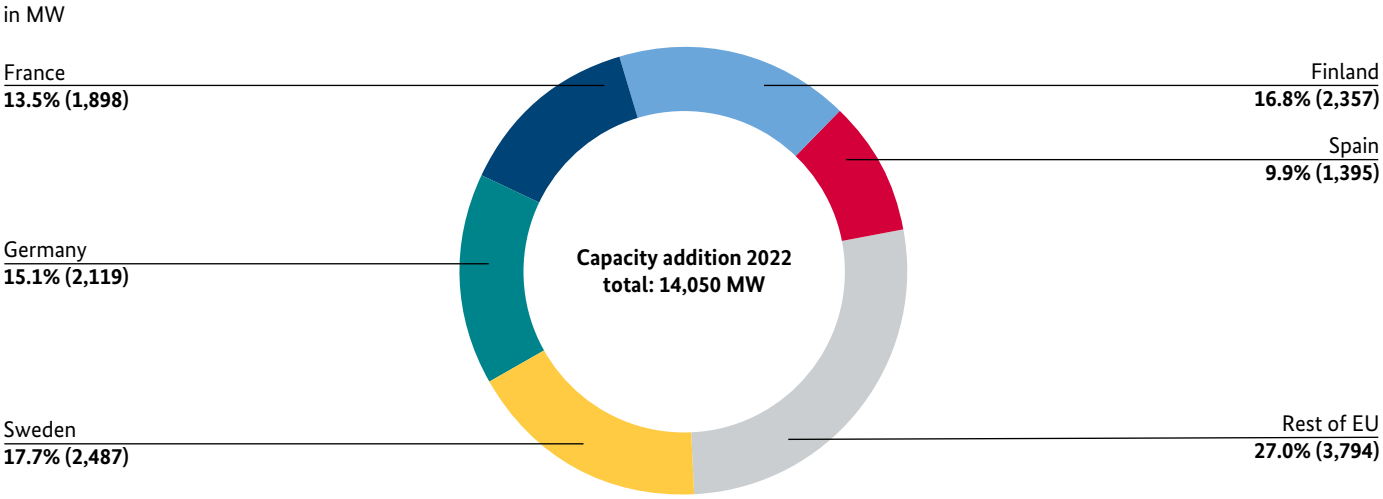
Figure 43: Wind energy onshore: Share of individual countries in the cumulative wind energy capacity (in MW), 2022



The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2023')

Source: IRENA ("Renewable Capacity Statistics 2023") [33]

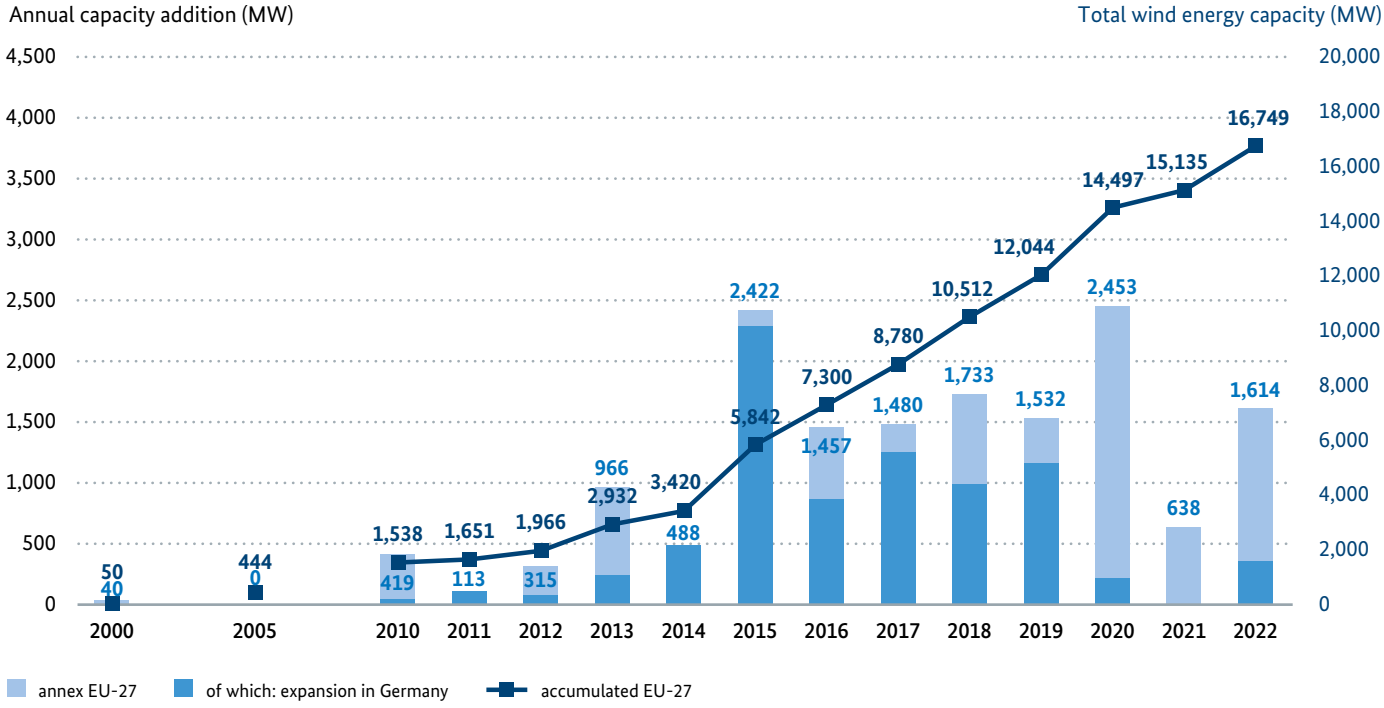
Figure 44: Wind energy onshore: Share of individual countries in the expansion of wind energy capacity (in MW), 2022



The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2023')

Source: IRENA ("Renewable Capacity Statistics 2023") [33]

Figure 45: Wind energy offshore: Development of the cumulative wind energy capacity (in MW) in the EU-27

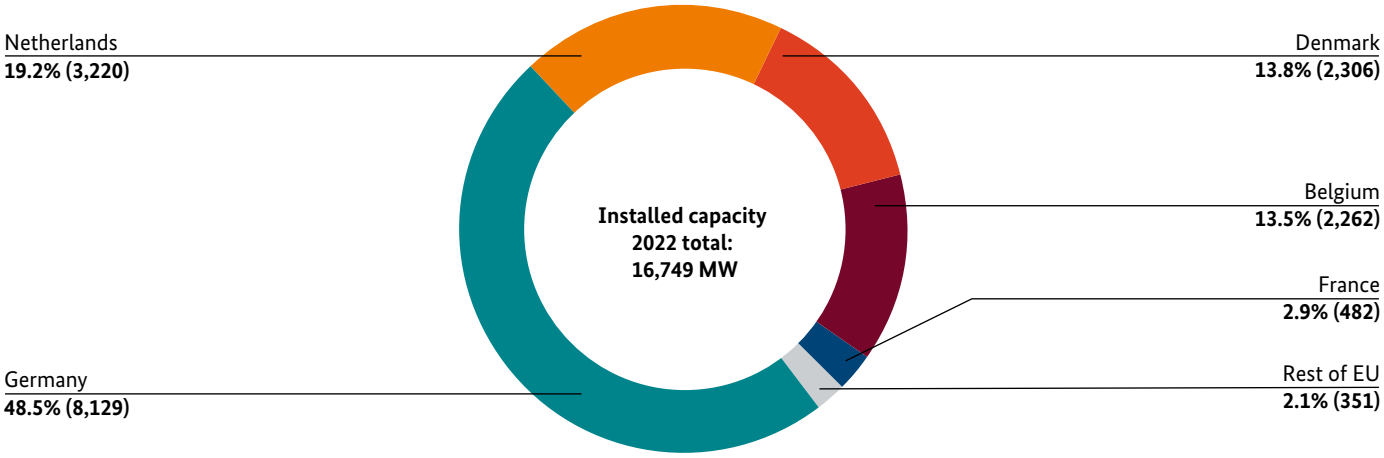


The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2023')

Source: Eurostat (nrg_inf_epcrw) [32]; IRENA ("Renewable Capacity Statistics 2023") [33]

Figure 46: Wind energy offshore: Share of individual countries in the cumulative wind energy capacity (in MW), 2022

in MW

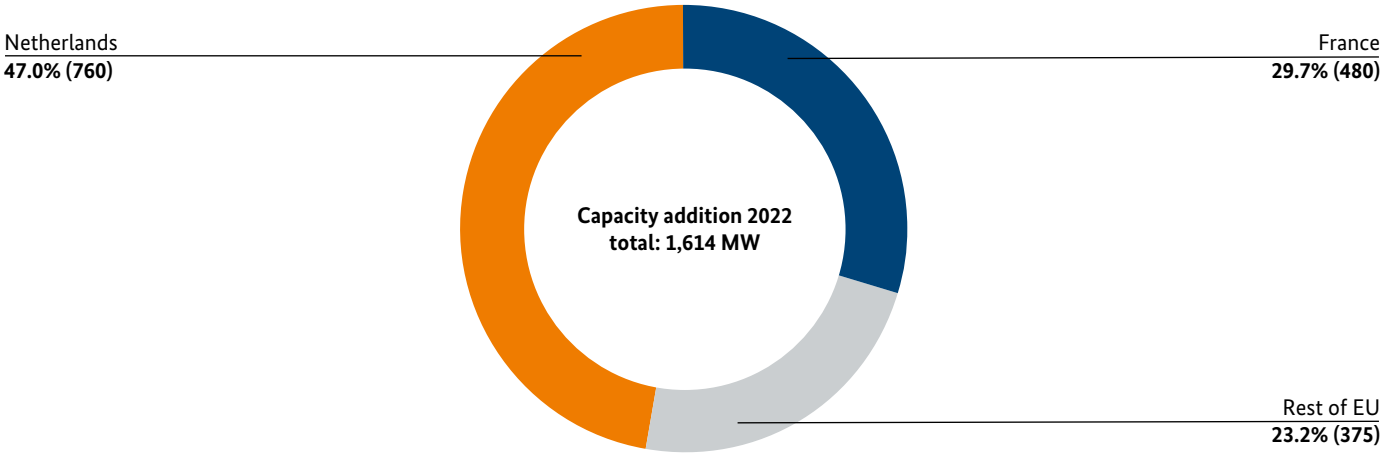


The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2023')

Source: IRENA ("Renewable Capacity Statistics 2023") [33]

Figure 47: Wind energy offshore: Share of individual countries in the expansion wind energy capacity (in MW), 2022

in MW



The 2022 wind capacity corresponds to the IRENA estimate ('Renewable Capacity Statistics 2023')

Source: IRENA ("Renewable Capacity Statistics 2023") [33]

Electricity generation from solar energy

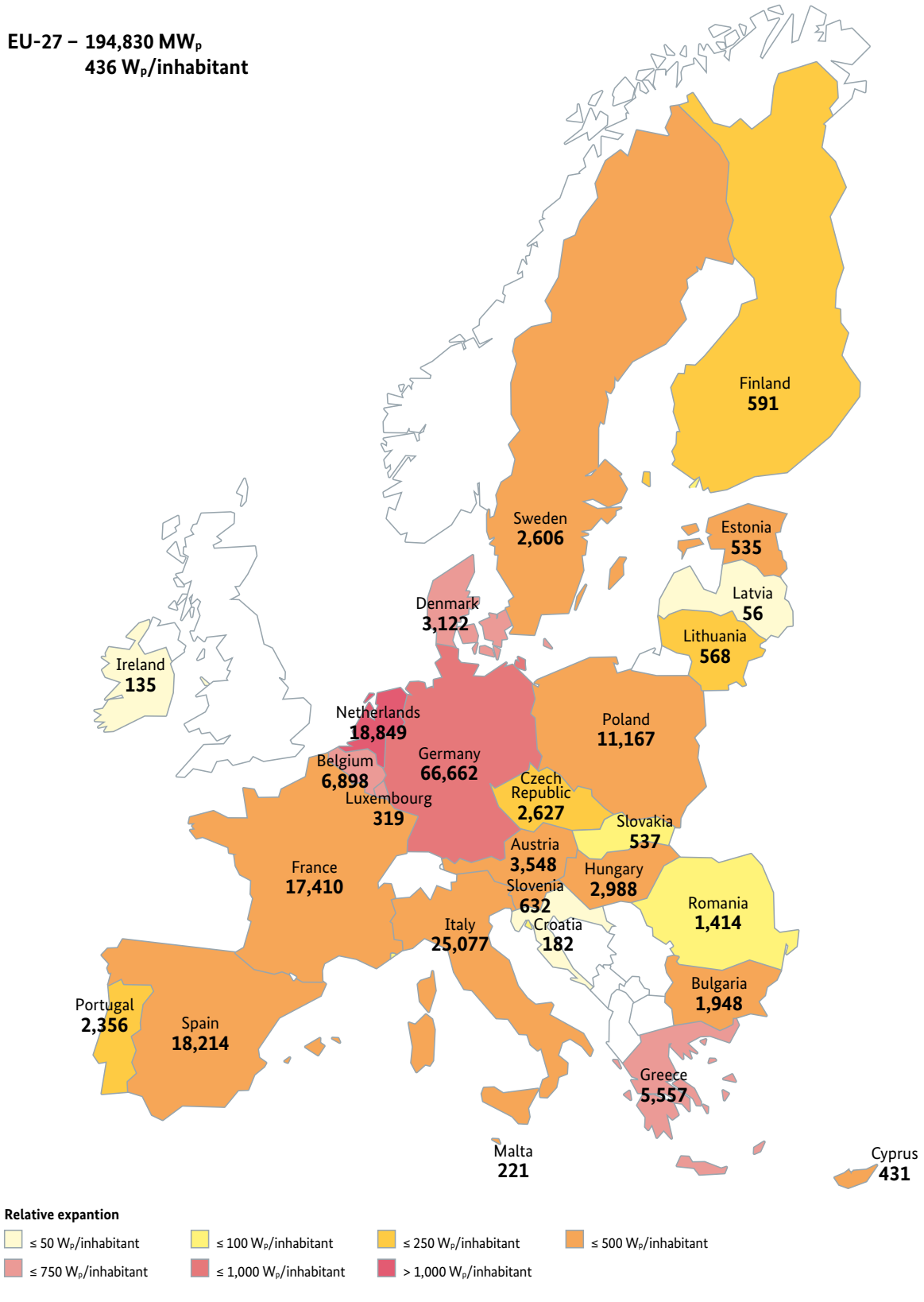
The expansion of solar energy in the EU made great strides in 2022. A record 35.1 gigawatts of newly installed photovoltaic capacity were registered. This was an additional 10 gigawatts or 40% more than in the previous year (2021: 25.1 gigawatts) [34]. In 2022, the number of new installations exceeded the gigawatt mark in eight Member States, up from six in the previous year. The highest growth was registered in Germany with 7.3 gigawatts, followed by Spain with 4.5 gigawatts and the Netherlands with 4.0 gigawatts. The other countries that expanded their capacity into the gigawatt range were Poland (3.8 gigawatts), France (2.6 gigawatts), Italy (2.5 gigawatts), Greece (1.3 gigawatts) and Sweden (1.0 gigawatt).

At the end of 2022, a total of 194.9 gigawatts of photovoltaic capacity was installed in the EU-27, 20% more than a year earlier (2021: 161,9 gigawatts). Germany had by far the highest share of total output at 66.7 gigawatts or 35%. Italy followed with 25.1 gigawatts, the Netherlands with 18.8 gigawatts, Spain with 18.2 gigawatts and France with 17.4 gigawatts. A different picture emerges when the installed capacity is compared to the population of the Member States. EU-wide, this figure was 436 watts per inhabitant at the end of 2022 (2021: 356 watts per inhabitant). At 1,083 watts, the Netherlands was well ahead of Germany with 802, Belgium with 599, Greece with 518 and Luxembourg with 510 watts per inhabitant.

Parallel to the increase in installed capacity, electricity generation from photovoltaic systems in the EU-27 also rose significantly by 30% year-on-year to 205.1 terawatt-hours in 2022 (2021: 157.8 terawatt-hours). Photovoltaics thus covered almost 7.3% of EU-wide electricity consumption (2021: 5.4%).

In addition to photovoltaic systems, solar thermal power plants are also used in the EU to generate electricity from solar energy although this only makes sense in southern European regions with a high number of sunshine hours. In the 1990s and 2000s, numerous such systems were developed in Spain, making the country a pioneer in solar thermal power generation both in the EU and worldwide. Although no plants have been added there in recent years, practically the entire installed capacity of solar thermal power plants in the EU – a good 2.3 gigawatts – is still located in Spain. With an annual electricity generation of around 5 terawatt-hours, these plants cover roughly 2% of Spain's annual electricity consumption. The Spanish government is pursuing the goal of doubling and then tripling solar thermal power generation capacity to 4.8 gigawatts by 2025 and to 7.3 gigawatts by 2030. So far, however, the corresponding tenders have not been successful and no power plants have been built. In 2022, only one plant with 8 megawatts was under construction in Italy [33].

Figure 48: Total installed photovoltaics capacity in the EU-27, 2021



Source: IRENA ("Renewable Capacity Statistics 2023") [33]

Table 33: Development of installed photovoltaics capacity in the EU Member States (EU 27) in MW

	2005	2010	2015	2016	2017	2018	2019	2020	2021	2022
	(MW)									
Austria	21	89	937	1,096	1,269	1,455	1,702	2,043	2,783	3,548
Belgium	2	1,007	3,132	3,329	3,621	4,000	4,637	5,573	6,012	6,898
Bulgaria	0	25	1,028	1,030	1,031	1,033	1,044	1,100	1,275	1,948
Croatia	0	0	48	56	60	68	85	109	138	182
Cyprus	1	7	76	84	110	118	151	229	315	464
Czech Republic	1	1,727	2,075	2,068	2,075	2,081	2,111	2,172	2,246	2,627
Denmark	3	7	782	851	906	998	1,080	1,304	1,704	3,122
Estonia	0	0	7	10	15	32	121	208	395	535
Finland	4	7	17	39	82	140	222	318	425	591
France	13	1,044	7,138	7,702	8,610	9,672	10,808	12,056	14,810	17,410
Germany	2,056	18,004	39,222	40,677	42,291	45,156	48,912	53,669	59,371	66,662
Greece	1	202	2,604	2,604	2,606	2,652	2,834	3,288	4,277	5,557
Hungary	0	2	172	235	344	728	1,400	2,131	2,968	2,988
Ireland	0	1	2	6	17	32	58	90	135	135
Italy	34	3,592	18,901	19,283	19,682	20,108	20,865	21,650	22,594	25,077
Latvia	0	0	0	1	1	2	3	5	7	56
Lithuania	0	0	69	70	74	82	103	164	255	568
Luxembourg	24	29	116	122	128	131	160	187	277	319
Malta	0	1	75	94	112	132	155	188	206	221
Netherlands	51	90	1,526	2,135	2,911	4,608	7,226	11,108	14,911	18,849
Poland	0	0	108	187	287	562	1,539	3,955	7,416	11,167
Portugal	2	134	447	513	579	667	901	1,100	1,646	2,536
Romania	0	0	1,326	1,372	1,374	1,386	1,398	1,383	1,394	1,414
Slovakia	0	19	533	533	528	472	590	535	537	537
Slovenia	52	3,873	4,704	4,713	4,723	4,764	8,807	10,136	13,715	18,214
Slowenien	0	12	238	233	247	247	278	370	461	632
Sweden	4	11	104	153	244	428	714	1,107	1,606	2,606
EU-27	**2,268**	**29,883**	**85,386**	**89,195**	**93,927**	**101,753**	**117,904**	**136,176**	**161,879**	**194,863**

Source: IRENA ("Renewable Capacity Statistics 2023") [33]

Renewable energy use in heat supply

The share of renewable energy in heat consumption in the EU-27 totalled 22.9% in 2021, slightly lower than in the previous year (2020: 23.0%). However, shares varied greatly among the Member States. The highest shares were in Sweden (68.6%), Estonia (61.3%) and Finland (52.6%). This was partly due to the high proportion of biomass in the heating market in these countries, but also to the widespread use of electric heating systems, particularly in conjunction with heat pumps. At 15.4%, Germany was still at the lower end of the scale, with only Luxembourg (12. 9%), Belgium (9.2%), the Netherlands (7.7%) and Ireland (5.2%) lower.

As biomass resources are limited with regard to the heating transition, the following technology-specific focus is on solar, environmental and geothermal heat.

Solar heating

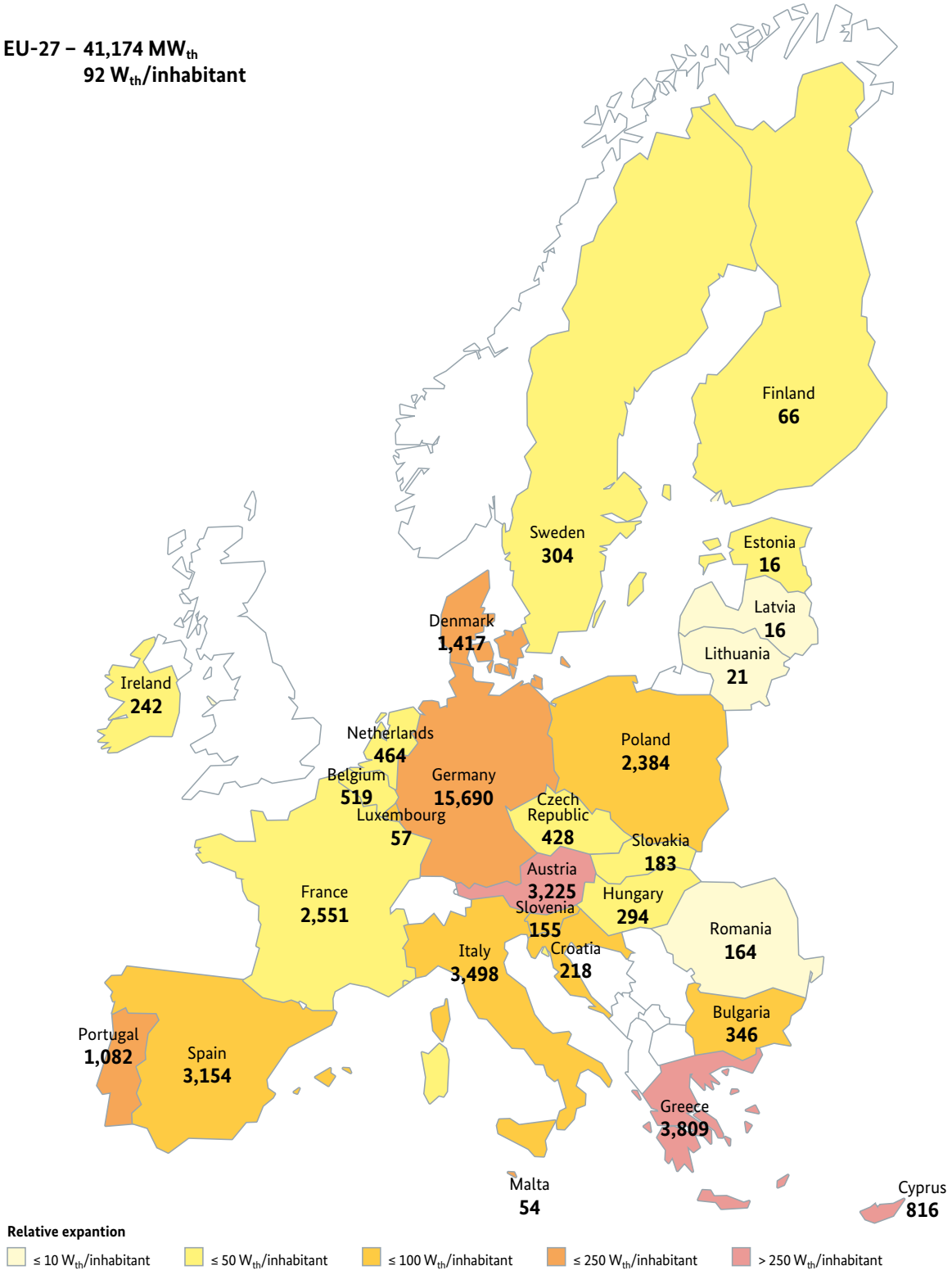
As a result of the energy crisis, the upward trend in the European solar thermal market already recorded in the previous year intensified in 2022. According to EurObserv'ER's Solar Thermal Barometer [35], at 2.37 million square metres, almost 12% more collector area was installed than in the previous year (2021: 2.12 million square metres). At the end of 2022, a collector area of over 58.8 million square metres was installed in the EU-27, corresponding to a thermal capacity of 41.2 gigawatts.

As in previous years, the German solar thermal market was the largest in the EU-27 and, at 709,000 square metres, accounted for around 30% of the entire European market. However, the markets in Greece (+17%) and Italy (+51%) in particular were next in terms of volume while recording stronger growth than in Germany (+11%), thus moving closer to Germany with 419,000 and 339,500 square metres of new collector area respectively. Other important solar thermal markets in Europe are: Poland with 210,000, France with 163,300 and Spain with 135,500 square metres of newly installed collector area.

In terms of the total collector area installed in the EU-27 at the end of 2022, Germany was by far the leader with 22.4 million square metres. Following close together behind were Greece with 5.4 million, Italy with 5.0 million, Austria with 4.6 million and Spain with 4.5 million square metres. A slightly different picture emerges when the installed solar thermal capacity is related to the number of inhabitants (see Fig. 49). Cyprus has the highest value here at 919 watts per inhabitant. Greece follows far behind with 355, Austria with 362 and Denmark with 243 watts per inhabitant. Germany follows in fifth place with 189 watts per inhabitant.

Further information on solar thermal energy in Europe can also be found on the EurObserv'ER website [34].

Figure 49: Total installed solar thermal capacity in the EU-27, 2022



Source: EurObservER 'Solar Thermal and concentrated Solar Power Barometer' [34]

Environmental and geothermal heat

As in Germany, the EU-wide focus on the heating transition is increasingly narrowing on the use of electricity in conjunction with heat pumps. Data for this is currently available up to 2021 when, according to EurObserv'ER [35], over 5.1 million new heat pumps were installed in the EU-27. The total number of heat pumps therefore came to more than 44.1 million systems. However, Italy, France, Spain, Portugal and Malta together accounted for around three quarters of these. In those countries, a large proportion of the heat pumps installed are not used for heating, but for air conditioning. Therefore, EU-27 Member States are not all comparable in their use of heat pumps.

When comparing Germany with similar countries, it is striking that more than twice as many systems were sold in the Netherlands in 2021 (368,000) than in Germany (175,000). Sales in Finland, at just under 129,000 systems, and Sweden, at 135,000 systems, were almost as high as in Germany. Comparing the number of heat pumps in relation to the population of the respective countries, the following picture emerges: While in Germany there is one heat pump for every 57 inhabitants, in Denmark there are 10, in Estonia 6 and in Finland and Sweden 5 inhabitants per installed heat pump.

Renewable energy in the transport sector

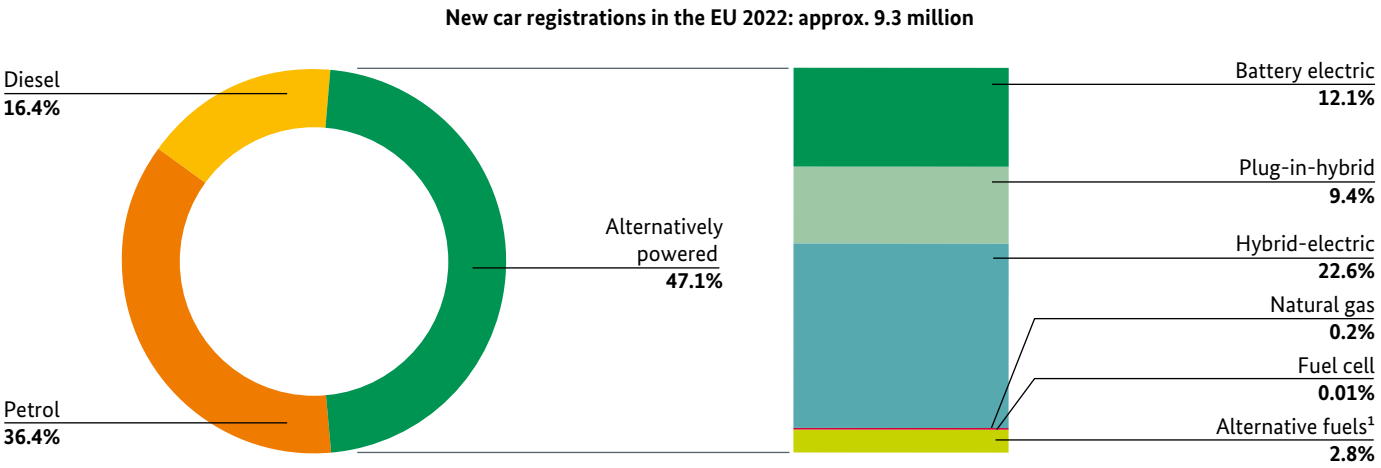
The share of renewable energy in final energy consumption in transport was 9.1% across the EU in 2021, a good one percentage point lower than in the previous year (2020: 10.3%). Shares of this varied greatly among Member States. Sweden and Finland had the highest percentages at 30.4% and 20.5% respectively, while Greece and Ireland had the lowest at 4.3% each.

After an interim downward trend in the use of biofuels since 2017, related in particular to discussions about their sustainability, sales have since increased across the EU. In 2022, the level of the previous year (21.9 million tonnes) was almost maintained at 21.8 million tonnes. Sales of bioethanol rose by a further 8% year-on-year to 5.2 million tonnes while sales of biodiesel fell by 1% to 15.56 million tonnes. For the development of biofuels, see also Table 34.

The electric drive has a decisive role to play in the EU-wide transition to sustainable and climate-friendly mobility. In order to achieve the objectives of the revision of RED-II, an accelerated expansion of the use of battery electric cars is of central importance throughout the EU. Although total passenger car registrations in the EU-27 fell by almost 5% in 2022, around 15% more electric vehicles (including plug-in hybrids) were on the roads than in the previous year (1.74 million) at just under 2 million new passenger cars. Among these, pure battery-electric cars in particular were on the rise. At 1.12 million cars, their sales increased by 28% compared to the previous year (2021: 0.88 million) while sales of plug-in hybrids declined slightly [36]. The largest number of new registrations of electric vehicles by far (including plug-in hybrids) was in Germany with around 816,000 cars. France followed with around 347,000, Sweden with 162,000, Italy with 118,000 and the Netherlands with 113,000 cars.

Table 34 shows the consumption of biofuels in the EU in 2021 and 2022 (provisional values according to Eurostat).

Figure 50: New car registrations in the EU-27, by fuel type, 2022



1 Biofuels and hydrogen

Source: ACEA [37]

Table 34: Consumption of biofuels in the EU Member States (EU-27) in 2021 and 2022

	2021				2022[1]			
	Bioethanol	Biodiesel	Other biofuels	Total	Bioethanol	Biodiesel	Other biofuels	Total
	kilotons (kt)				kilotons (kt)			
Austria	104	279	0	382	76	199	0	275
Belgium	220	650	5	876	236	672	19	927
Bulgaria	32	172	0	204	31	180	0	211
Croatia	0	64	0	65	0	15	0	15
Cyprus	0	13	0	13	0	10	0	10
Czech Republic	129	354	0	483	121	332	0	453
Denmark	146	207	5	357	154	183	2	339
Estonia	0	0	0	0	0	0	0	0
Finland	167	587	37	791	173	486	46	705
France	1,067	2,745	4	3,816	1,284	2,769	30	4,083
Germany	1,170	2,612	145	3,927	1,233	2,622	141	3,996
Greece	119	192	0	310	0	0	0	0
Hungary	90	131	0	221	95	149	0	244
Ireland	23	115	0	138	24	163	0	187
Italy	32	1,573	896	2,500	41	1,533	600	2,174
Latvia	18	41	0	60	16	9	0	24
Lithuania	31	116	0	147	29	98	0	128
Luxembourg	0	0	0	0	0	0	0	0
Malta	0	11	0	11	0	13	0	13
Netherlands	400	826	24	1,250	576	1,210	17	1,803
Poland	272	978	2	1,252	290	956	3	1,249
Portugal	22	328	0	350	36	297	0	333
Romania	189	425	0	614	189	425	0	614
Slovakia	72	156	0	228	80	165	0	245
Slovenia	0	108	0	108	0	85	0	85
Spain	177	1,419	4	1,599	160	1,404	3	1,568
Sweden	332	1,616	239	2,187	356	1,586	148	2,090
Region EU-27	**4,811**	**15,718**	**1,362**	**21,890**	**5,201**	**15,561**	**1,011**	**21,772**

1 Figures are provisional

Source: Eurostat [NRG_CB_RW] [38]

Further information on the topic of biofuels in Europe can also be found on the EurObserv'ER website [39].

Part III: Worldwide use of renewable energy

At the UN Climate Change Conference of December 2015 in Paris, the international community agreed to limit global warming to well below 2 degrees, preferably to 1.5 degrees. The Paris Agreement, a treaty under international law that came into force in November 2016, is recognised by all countries of the world. In order to limit the consequences and risks of global warming which have become increasingly apparent since then, compliance with the Paris goals is essential. The success of global climate protection depends on the phasing out of fossil fuels and the expansion of renewable energy sources.

In 2013, the 193 Member States of the United Nations (UN) unanimously declared the years 2014 to 2024 to be the 'Decade of Sustainable Energy for All' with the goal of access to sustainable energy for everyone. Behind this was the fact that 1.4 billion people, or around 20% of the world's population, had no access to electricity and therefore no real possibility for development. In order to counter climate change at the same time, energy production should be sustainable and environmentally friendly. In detail, the initiative pursues the goal of giving all people worldwide access to electricity and modern forms of energy and to double energy efficiency as well as the share of renewable energy sources in the global energy supply.

Two years before the end of the decade, we are still a long way from achieving this goal, although solar and wind energy have in the meantime become the cheapest energy sources [40]. If we exclude traditional biomass use from the statistics, especially cooking over an open fire, which from several aspects is not sustainable, then according to REN 21 [38], the share of renewable energy in total global final energy consumption increased by only 43% in the decade between 2011 and 2021 and the share of electricity consumption by only 39%. We are therefore still a long way from achieving the targeted doubling.

In its latest World Energy Transitions Outlook [41] published in June 2023, the International Renewable Energy Agency (IRENA) states that an immediate course correction in the expansion of renewable energy sources is needed to realise the 1.5-degree target. The report acknowledges electricity generation capacity from renewable energy sources is growing. At the same time, it points to the widening gap between what has been achieved and what is still needed. According to the Intergovernmental Panel on Climate Change (IPCC), reducing greenhouse gas emissions by half by 2030 on a 1.5-degree path would require an annual increase in renewable energy capacity of 1,000 gigawatts. Although a new record value was set in 2022 according to REN 21 [38], the 348 gigawatts achieved was just a third of what is needed. Therefore, it is urgent to triple the annual expansion rates of renewable energy.

Global efforts in this direction are increasing. The worsening climate crisis and now the energy crisis resulting from the Russian war of aggression against Ukraine have also spurred change. It has become clear that many countries can only free themselves from long-term, risky dependencies on fossil fuel imports with the help of domestic renewable energy sources. At their April 2023 meeting, the G7 agreed for the first time ever on collective targets for the expansion of renewable energy. By 2030, 150 gigawatts of offshore wind energy capacity and 1,000 gigawatts of photovoltaic capacity are to be added. The G7 also committed for the first time to phasing out the use of fossil fuels. Although no agreement to this effect was reached at the meeting of G20 energy ministers in July 2023, a large majority of G20 countries have already committed to the goal of tripling renewable energy sources by 2030.

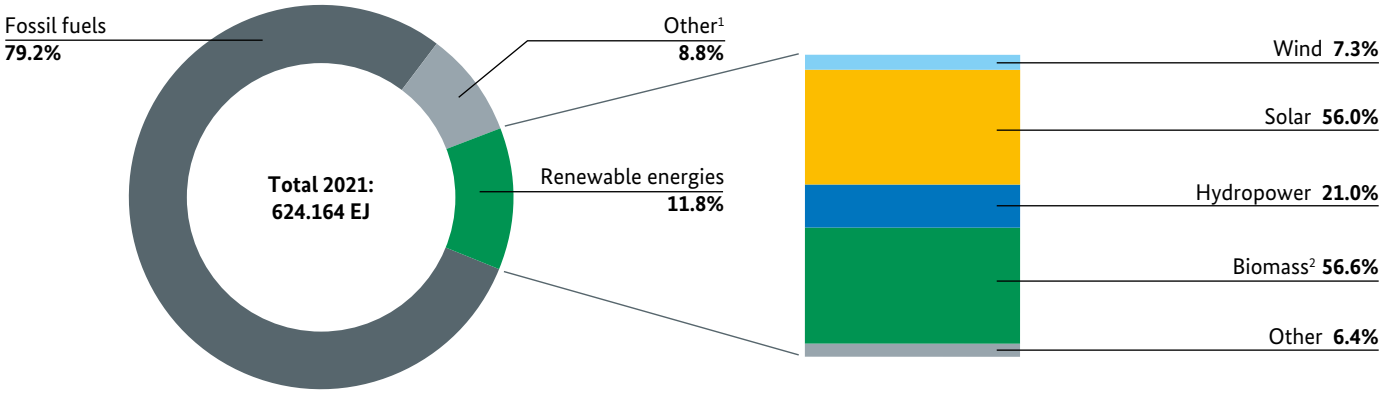
The current state of global renewable energy use, particularly for electricity generation but also in other areas, is presented below. In each case it was drawn up in accordance with the data available at the time of writing this brochure. It largely but not yet completely refers to the year 2022 and draws on various sources. This is indicated at the respective points. It should be noted that the data for Germany contained in international reports differs in some cases from that in Part I of this brochure, but they are used here for the sake of consistency.

Global final energy consumption

According to the International Energy Agency [42], the share of renewable energy sources in global final energy consumption in 2021 was 11.8%, slightly higher than in the previous year (2020: 11.6%). Traditional biomass utilisation with a share of 3.9% is not included in this figure. Fossil fuels

such as coal, oil and gas accounted for 79.2% and nuclear energy for 4.9%. Of the 11.8 % from renewable energy sources, 6.6% were accounted for by biomass, 2.5% by hydropower, 1.1% by wind energy and 0.9% by solar energy, with the last two sectors showing the highest growth rates compared to the previous year at 17% and 19% respectively. The remaining 0.7% were accounted for by other renewable energy sources, primarily geothermal.

Figure 51: Distribution of global final energy consumption (FEC), 2021



1 Other energy sources include nuclear energy and non-sustainably used traditional biomass

2 Modern biomass

1 EJ (exajoule) = 1,000 petajoules or 277,8 terawatt hours see also the conversion factors in the Annex

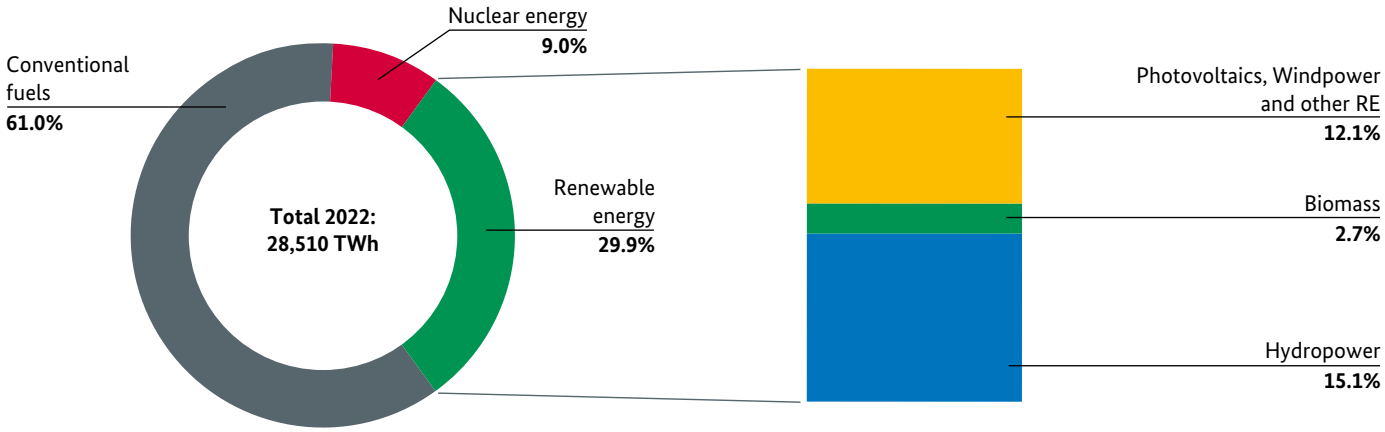
Source: IEA [42]

Power generation from renewable energy sources

As in Germany and the EU, the most significant growth in renewable energy globally is taking place in electricity generation. According to REN21 [43], 29.9% of the electricity generated worldwide in 2022 was produced from renewable energy sources, a good one and a half percentage points more than in the previous year (2021: 28.3%). Fossil fuels, primarily coal and nuclear energy, generated 61% and 9% of electricity respectively.

With a good 15% share of global electricity generation, hydropower is still the most important source of electricity among the renewable energy sources. As in Germany and Europe, global growth of renewable energy sources in the electricity sector is mainly due to wind energy and photovoltaics. Their combined share of global electricity generation in 2022 was 12.1%, around two percentage points more than in the previous year. This means that about one-third more electricity is produced worldwide from solar and wind than from nuclear energy.

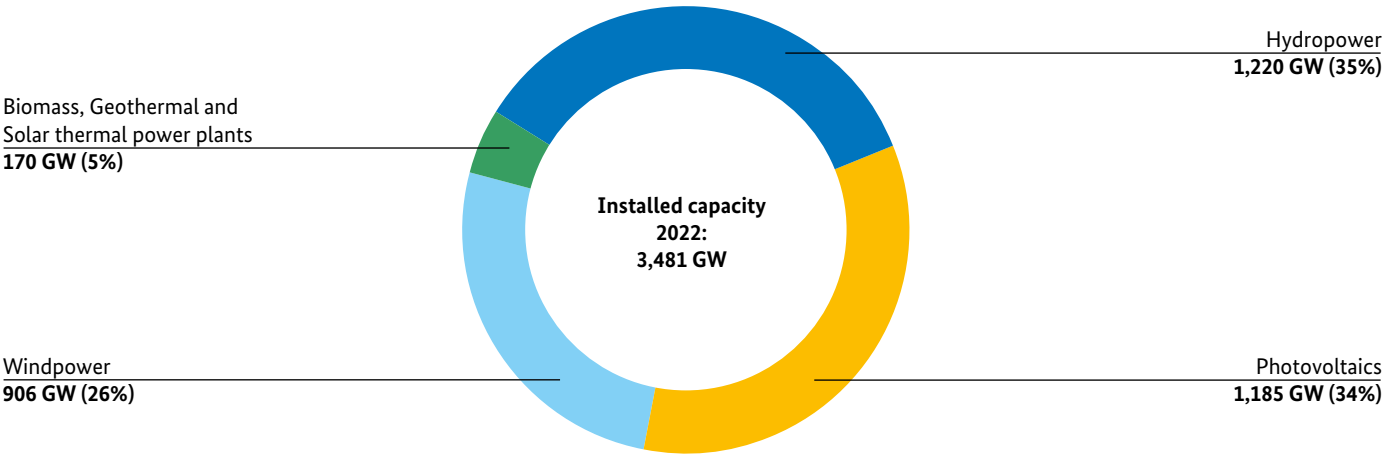
Figure 52: Distribution of global electricity generation, 2022



Source: IEA [42]

Currently, the vast majority (83%) of new electricity generation capacity worldwide is based on renewable energy sources, primarily solar and wind. In 2022, 348 gigawatts of electricity generation capacity from renewable energy sources were newly installed, 13% more than in the previous year (2021: 306 gigawatts). Photovoltaics accounted for the largest share of this at 243 gigawatts, a 34% growth rate compared to the previous year (2021: 182 gigawatts). With a 70% share, photovoltaics was even more dominant in the expansion of renewables in the electricity sector than in the previous year (2021: 59%). In 2022, wind energy accounted for a good 22% of the expansion, or 77 gigawatts, while hydropower accounted for 22 gigawatts and biomass, geothermal and marine energy for 5 gigawatts. Nevertheless, according to IRENA (WETO 2023), significantly higher annual expansion rates, particularly for photovoltaics (of 551 gigawatts/year) and wind energy (of 329 gigawatts/year), will be necessary by 2030 in order to achieve the 1.5-degree target.

Figure 53: Total installed power generation capacity based on renewables at the end of 2022



Source: REN21: Renewables 2023 Global Status Report [43]

At the end of 2022, 3,481 gigawatts of electricity generation capacity from renewable energy sources were installed worldwide. The total operating performance grew by around 11% compared to the previous year. At 1,215 gigawatts or 35.3%, photovoltaics accounted for the largest share, overtaking hydropower for the first time, which accounted for 32.9% or 1,132 gigawatts. Wind energy followed in third place with 932 gigawatts or a 27.1% share. Of the nearly 5% remaining, 149 gigawatts were attributable to biomass, 15 gigawatts to geothermal and 6 gigawatts to solar thermal power generation plants.

Photovoltaics

The global photovoltaic market grew rapidly in 2022 and with an expansion of 243 gigawatts exceeded the previous year's figure by 34% (2021: 182 gigawatts). The vast majority of this growth is once again attributable to China, which alone was responsible for 106 gigawatts or 44% of the total newly installed capacity. China thus almost doubled its previous year's expansion (2021: 55 gigawatts). The USA followed far behind with 18.6 gigawatts of new capacity installed, 16% less than in the previous year. India was almost level for the first time with 18.1 gigawatts. Germany followed with 7.5 gigawatts after Brazil (9.9 gigawatts) and Spain (8.1 gigawatts).

By the end of 2022, 1,185 gigawatts of photovoltaic capacity had been installed worldwide. At 414 gigawatts, 35% of the capacity was located in China, which covered almost 5% of China's electricity consumption in 2022 through the generation of 418 terawatt-hours of solar power. The share was roughly the same as in the USA, which was in second place in terms of total output with 144 gigawatts, ahead of Japan with 85 gigawatts, India with 79 gigawatts and Germany with 67 gigawatts.

Wind energy

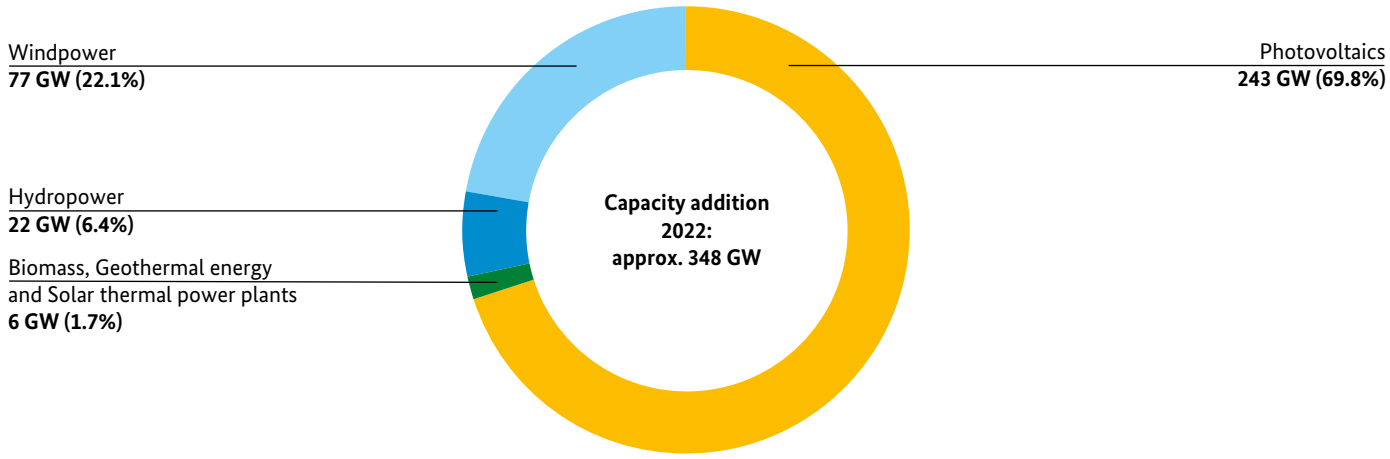
In 2022, around 77 gigawatts of new wind energy capacity were connected to the grid worldwide, around 17% less than in the previous year. The decline was mainly due to lower installations at sea, which had reached a very high level in the previous year. In regional terms, China and the USA were the main contributors to the decline while Europe was the only region to record rising installation figures in 2022. China continued to account for the largest share of new wind energy installations even though installations there were around a fifth lower than in the previous year at 37.6 gigawatts. The USA accounted for the second-largest share of new installations with 8.6 gigawatts, around 37% fewer than in the previous year. It was followed by Brazil with 4.1 gigawatts, Germany with 2.7 gigawatts and Finland with 2.4 gigawatts.

This means that 906 gigawatts of wind energy capacity were connected to the grid worldwide at the end of 2022. China accounted for the largest share with 365 gigawatts or 40% and thus covered 8.8% of its electricity consumption in 2022 – one percentage point more than in the previous year and almost three percentage points more than in 2020. A good 144 gigawatts of wind energy capacity were installed in the USA at the end of 2022, followed by Germany with 66 gigawatts and India with 42 gigawatts.

The other technologies play only a subordinate role in the global expansion of the use of renewable energy sources to generate electricity. In 2022, 149 gigawatts of biomass power generation capacity were installed worldwide with China accounting for the largest share at 34 gigawatts, followed by Brazil with 17 gigawatts, the USA with 11 gigawatts and India with 10 gigawatts. Hydropower, with an installed capacity of 1,220 gigawatts and electricity generation capacity of 4,429 terawatt-hours (a good 15% of global electricity consumption), is still the most important source of electricity among renewables. However, its growth in 2022 was significantly below that of photovoltaics and wind energy with an expansion of 22.2 gigawatts or just under 2%. Growth in electricity generation from geothermal energy was equally low. At the end of 2022, a capacity of 14.6 gigawatts was installed worldwide, only 0.2 gigawatts more than in the previous year.

If we look at developments in the various regions of the world over the last decade or so, we can see that electricity generation from renewable energy sources has increased significantly in Europe and North America. At the same time, electricity consumption has remained roughly the same, meaning that the share of renewable energy sources in

Figure 54: Expansion of power generation capacity based on renewables, 2022



Source: Renewables 2023 Global Status Report [43]

total electricity consumption has also increased significantly. In Asia, on the other hand, although electricity generation from renewable energy sources grew rapidly, its share of total electricity generation was significantly lower. This is because the growth in renewable energy sources was only able to cover around half of the increase in electricity demand. In general, most developing and emerging countries have lagged far behind in the growth of renewable energy sources despite their great natural potential and the high demand for energy access and security that could be met (IRENA WETO 2023). Efforts to expand renewable energy sources should therefore be stepped up in these regions in particular.

Renewable energy sources in the other sectors

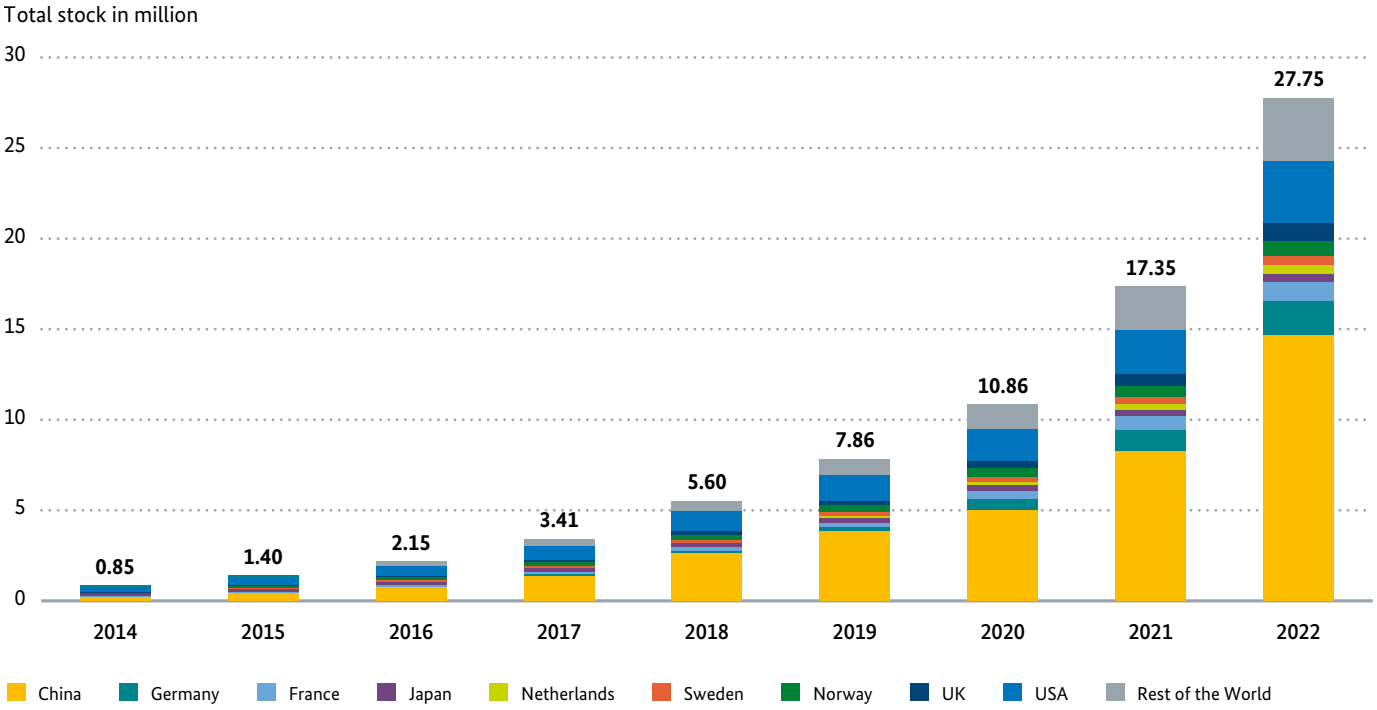
The global share of renewable energy sources in other sectors is growing even more slowly than in the electricity sector. According to REN 21, the share of renewables in heat consumption (excluding traditional biomass use) was 11.5% in 2020 and has only increased by around two and a half percentage points over the course of a decade (2010: 8.9%) [43]. This is quite problematic when considering that electricity currently accounts for just under 23% of global final energy consumption, while heat accounts for almost 49%.

Of the 11.5% of renewable energy sources in the heating sector in 2020, 7.9% were biomass (including local and district heating), 2.3% were renewable electricity and 1.2% were solar and geothermal energy. The latter share has tripled over the past 10 years. Global sales of heat pumps rose again by 11% in 2022. Nevertheless, considerable room for improvement still exists as heat pumps accounted for less than 10% of newly installed heating systems in 2022 while half were fossil-based. The world's largest heat pump market is China, but around 4.3 million new heat pumps will also be installed in the USA in 2022 alone, outstripping gas heating systems for the first time. In contrast, the global expansion of solar thermal systems fell by 9% in 2022, primarily due to a decline of more than 12% in China, the world's largest solar thermal market with almost three quarters of the total installed solar thermal capacity. In total, solar thermal systems with a capacity of 522 gigawatts were in operation worldwide at the end of 2022 [43].

The transport sector has an even greater need to catch up than the heating sector, as fuels accounted for almost 29% of final energy consumption worldwide in 2021 [43]. The key technology for climate protection in the transport sector is electromobility, which also proved to be a significant growth market in 2022. The global number of passenger cars and light commercial vehicles with battery-electric drive systems (including plug-in

hybrids) rose by 60% to 27.75 million in 2022. With 6.5 million new vehicles or a share of around 61%, China was again the driving force, followed by the USA with around one million vehicles and Germany with just under 833,000 vehicles. At 14.6 million vehicles, China was also well ahead of the USA with 3.4 million at the end of the year [36].

Figure 55: Global fleet of electric vehicles



The figures cover passenger cars and light commercial vehicles with only battery-electric engines or with range extenders and plug-in hybrids.

Source: ZSW [36]

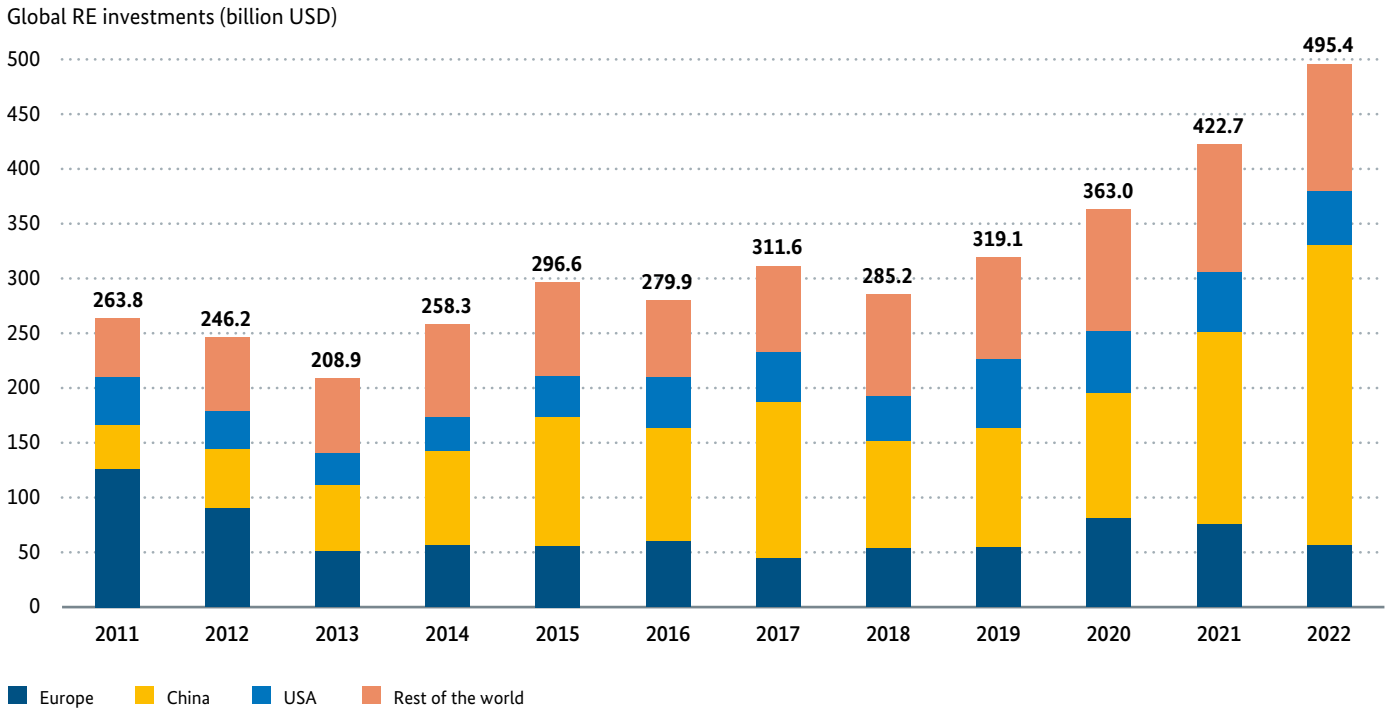
The IEA anticipates that ambitious political programmes in the major economies such as the Fit for 55 package in the EU and the Inflation Reduction Act in the United States will further increase the market share of electric vehicles in coming years. By 2030, the average share of electric cars in total sales in China, the EU and the USA is expected to rise to around 60% [42].

Worldwide investments in renewable energy sources

For years, investments in renewable energy installations have been a significant economic factor worldwide. The amount of annual investment has fluctuated in the past but has shown a steady upward trend for the past four years. Global investment in renewable energy sources for power generation (excluding large-scale hydropower) reached a new all-time high of over US$ 495 billion in 2022, or 17% more than in the previous year. The clear driver of rising investment in 2022 was photovoltaics, which increased by 36% year-on-year to US$ 307.5 billion. Investments in photovoltaics accounted for 62% of total investments in renewable energy sources for electricity generation (excluding large-scale hydropower). Considering the total global investment in electricity generation capacity, renewable energy sources accounted for 74% in 2022, or three times as much as was invested in fossil and nuclear power plants combined. Nevertheless, investment in renewable energy falls short of what is needed to achieve the 1.5-degree target: according to IRENA (WETO 2023), this would require an almost threefold increase in annual investment in renewable energy to USD 1.3 trillion. It should be noted that this fig-

ure does not include investments in infrastructure and electrification, both of which are needed to restructure the energy system and effectively protect the climate, but which also contribute to a global energy transition.

Figure 56: Investment in renewable energy sources by region



Source: REN21: Renewables 2023 Global Status Report [43]

In 2022, China alone was responsible for more than US$ 274 billion, or around 55% of total investments. This was 56% more than the previous year and mainly due to investments in photovoltaics, which were almost 80% higher than in the prior year at over US$ 164 billion. In the USA, on the other hand, investments fell once again by 10% to US$ 49.5 billion and in Europe by as much as 26% to just under US$ 56 billion [43]. Developing and emerging countries and particularly regionally in Africa, continue to lag significantly behind in terms of investment in renewable energy sources (IRENA WETO 2023).

Table 35: Worldwide investments disaggregated by renewable energy sector

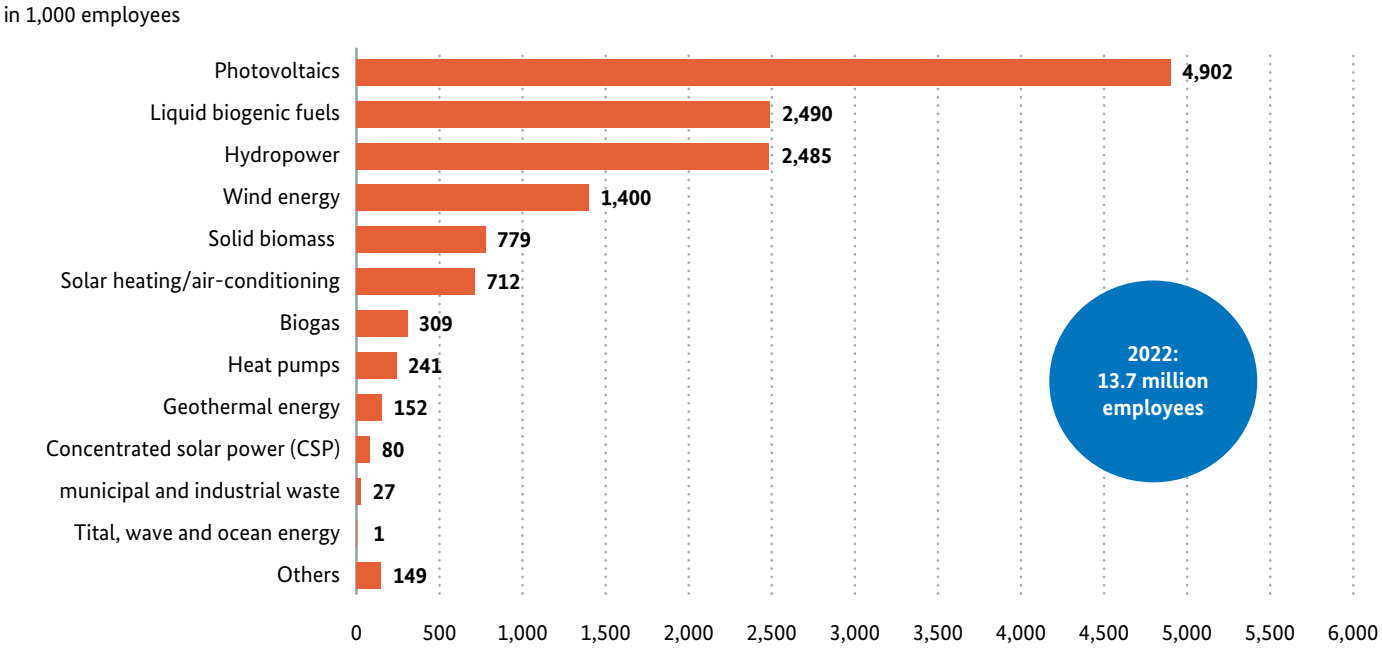
	Solar energy	Wind energy	Other RE
	RE investments (billion USD)		
2018	138.3	125.6	21.3
2019	134.2	160.0	24.8
2020	179.0	166.7	17.4
2021	226.2	176.7	19.8
2022	307.5	174.5	13.5
% change to 2021	**36%**	**-1%**	**-32%**

Source: REN21: Renewables 2023 Global Status Report [43]

Employment in the renewable energy sector

According to IRENA [45], the number of people employed in the renewable energy sector increased by 1 million worldwide in 2022, which comes to 13.7 million people employed in the industry. Almost two- thirds of the jobs were located in Asia, 41% in China alone. At 4.3 million, the photovoltaic industry provided the most jobs, followed by bioenergy with a good 3.9 million of which 2.5 million were held in the biofuel industry. This was followed by hydropower with 2.5 million jobs and onshore as well as offshore wind energy with 1.4 million jobs.

Figure 57: Persons employed in the renewable energy sectors, 2022



Source: IRENA – Renewable Energy and Jobs – Annual Review 2023 [45]

Appendix

International networks for renewable energy sources

International Renewable Energy Agency – IRENA

The International Renewable Energy Agency (IRENA) is an international governmental organisation for the global promotion of renewable energy development based in Masdar City, United Arab Emirates. It supports countries in their transition to a sustainable energy future and serves as the main platform for international cooperation. More than a decade ago, around 70 countries founded this platform for international cooperation to promote the global energy transition. It has since grown to 168 members (including the EU), with another 16 countries in the process of joining.

IRENA is the global voice of renewable energy in international debates. It is also a platform for exchange between countries on successful models of renewable energy growth, effective policies, capacity expansion, financing mechanisms and energy efficiency measures related to renewable energy. As a knowledge repository, it provides access to information on renewable energy ranging from technological expertise to economic data, opportunities, and development scenarios for renewable energy sources. It is also tasked with advising industrialised, developing and emerging economies on driving growth in renewable energy.

Cooperation with other players

As an international organisation, IRENA seeks to support all relevant players in their efforts to bring about the large-scale use of renewable energy technologies around the world. Vital partners include governments, national and international institutions, non-governmental organisations and the private sector.

In order to involve the member states more closely in its work, IRENA has designed thematic Collaborative Frameworks. The current eight Collaborative Frameworks are:

- Enhancing Dialogue on High Shares of Renewables in Energy Systems
- Geopolitics of Energy Transformation
- Green Hydrogen
- Hydropower
- Just and Inclusive Energy Transition
- Ocean Energy/Offshore Renewables
- Critical Materials for the Energy Transition
- Project Facilitation to support on-the-ground Energy Transition

The member states take turns in their role as co-facilitators of the Collaborative Frameworks. Germany currently co-chairs the Collaborative Framework on Green Hydrogen with the United Arab Emirates.

Work programme and budget

IRENA encourages governments to adopt supportive policies for renewable energy investments. It provides practical tools and policy advice for this purpose.

The work programme for 2022/2023 is based on the following four strategic objectives:

1. empower effective policy and decision-making by providing knowledge and analyses on the energy transition at global, national and sectoral levels;

2. shape the global discourse on energy transformation by providing relevant, timely, high-quality information and data;

3. provide an inclusive platform for all ‘stakeholders’ to promote knowledge exchange and support the use of renewable energy on the ground;

4. support country-level decision-making to accelerate the renewables-based transformation in the respective countries and to further develop emissions reduction strategies.

IRENA's work to implement these strategic goals is divided into four thematic programme areas:

1. Centre of Excellence for Energy Transformation
2. Global Voice of Renewables
3. Network Hub for Energy Transformation
4. Source of Advice and Support

In line with these goals, IRENA offers a wide range of products and services, including:

- Its flagship report World Energy Transitions Outlook (WETO)
- Statistics on the installed capacity of renewable energy
- Cost studies of renewable energy sources
- Surveys of employment in the renewable energy sector
- Renewables Readiness Assessments conducted in partnership with governments and regional organisations to advance renewable energy development
- The Global Atlas, which maps resource potential by source and location
- Studies on the benefits of renewable energy
- REmap, a roadmap to double the use of renewable energy worldwide by 2030
- Publications on renewable energy technologies
- Promotion of regional renewable energy planning
- Renewable energy project development tools

Main organs and structure

IRENA has three main bodies. The Assembly, which meets annually, is IRENA's highest decision-making authority. It consists of all countries that have ratified the statute.

The Council, which consists of 21 members and meets twice a year, examines reports and documents, in particular the IRENA work programme and budget, and submits them to the Assembly for decision.

The Secretariat implements IRENA's work programme and assists the Assembly, Council and other subordinate bodies in carrying out their functions. The Secretariat is headed by IRENA's Director General, Francesco La Camera from Italy. It is divided into three main departments, two of which are based in Abu Dhabi and one in Bonn. The headquarters is in Abu Dhabi (United Arab Emirates). The IRENA Innovation and Technology Centre (IITC), one of IRENA's three specialist departments, is located in Bonn. IRENA currently has around 170 employees.

The International Energy Agency – IEA

The International Energy Agency, IEA, based in Paris, is one of the central global energy organisations. As an independent institution within the OECD, it is the voice of the energy-consuming industrialised countries and currently unites 31 OECD countries, 11 association countries and four accession countries. Chile, Colombia, Israel and Latvia are in the process of joining the IEA. In view of the strong growth in energy demand outside the OECD, the IEA is also expanding and deepening its cooperation with countries that are not members of the OECD and therefore cannot join the IEA under the current rules (so-called "association countries"). Since the end of 2015, the IEA has agreed on association with Argentina, Egypt, Brazil, China, India, Indonesia, Morocco, Singapore, South Africa and Thailand. The most recent association country status was granted to Ukraine in July 2022.

The IEA was founded in 1974 in response to the first oil crisis with the aim of ensuring a disruption-free oil supply. To this end, the member countries commit to holding emergency reserves of oil for at least 90 days. The focus of its work has evolved and broadened over the past decades towards a sustainable energy policy, the elaboration of market reforms, the development of innovative energy technologies and the increasing, active involvement of emerging economies in energy policy issues. The most important common goals are:

- securing a reliable energy supply for the member countries, including through the establishment and maintenance of joint IEA measures for emergency supply in the event of a failure of oil imports (oil stockpiling and distribution);
- monitoring and stabilising global energy markets and price developments;
- supporting the achievement of net-zero greenhouse gas emissions by the mid-century worldwide and the switch to environmentally friendly and sustainable energy sources;
- cooperating internationally to develop new energy technologies and a sustainable global energy system.

The IEA has developed into a central forum for the international exchange of experience and policy advice on almost all energy policy areas. Issues relating to the development of renewable energy sources and their integration into energy systems occupy an important position in this context. Regular IEA country reviews with energy policy recommendations as well as the annual World Energy Outlook (WEO) as the comprehensive international energy policy reference document with a current forecast horizon up to the year 2050 are particularly influential publications of the IEA, which are highly regarded worldwide in the formulation of national energy policies.

The IEA regularly publishes a large number of other reports, studies and publications on various topics in the energy sector, including:

- Global Energy Review: This semi-annual report provides a preliminary analysis of global energy consumption, CO2 emissions and the development of renewable energy sources. It contains current data and trends and provides insights into energy development on a global level.
- Renewables: The annual publication provides comprehensive information and statistics on the development and use of renewable energy sources worldwide. It contains data on renewable energy technologies, capacities, production and investments.
- Energy Technology Perspectives (ETP): This report analyses technologies and policy options for a sustainable energy future. It analyses various energy technologies, energy efficiency measures and policy instruments to support the transition to a low-carbon energy economy.
- Energy Efficiency Market Report (EEMR): This report analyses the energy market worldwide and advances in energy efficiency measures. It provides insights into energy consumption, energy efficiency potential and policy measures to promote energy efficiency.
- Technology Roadmaps: The IEA publishes a series of technology roadmaps for various energy technologies, including renewable energy sources, energy efficiency, hydrogen, carbon capture and storage (CCS) and many others. These roadmaps provide a comprehensive overview of the current state of development, potential and challenges of various technologies.

This is just a sample of IEA publications. The organisation regularly publishes further reports on specific topics, regions and energy sectors for governments, industry and other interest groups under “Analysis” and “Data” on its website.

Main organs and structure

All decisions in the IEA are taken by the member countries. The highest decision-making level is the Governing Board, which determines the strategic direction of IEA activities. The IEA Secretariat in

Paris with approximately 330 employees provides the organisational structure for carrying out the many tasks of the IEA. The BMWK is represented in the IEA's Renewable Energy Working Party (REWP). The IEA is headed by Executive Director Dr Fatih Birol from Turkey.

Since 2011, the Renewable Industry Advisory Board (RIAB) has also been an advisory board of companies in the renewable energy sector, which exchanges information on market and sector developments in regular workshops and supports the work of the REWP and the IEA Secretariat with relevant information. German companies are also represented in the RIAB.

Another IEA body is the Committee on Energy Research and Technology (CERT). This is responsible for coordination and cooperation in global energy research. Among other things, the CERT oversees the participation of German research partners in the numerous international research programmes (Technology Collaboration Programmes, TCP) of the IEA's Energy Technology Network. Germany is currently involved in 24 of 39 ongoing TCPs. Further information on the research programmes is published at BMWK (in German only).

Energy cooperation in the G7 and G20

In 1975, the Group of Seven (G7), comprising the USA, Japan, Germany, the UK, France, Italy and Canada, brought together the world's leading economic and political nations for the first time in an informal forum of heads of state and government to take responsibility for key global issues and actively contribute to developing constructive answers. A summit declaration (communiqué) with the most important results is adopted at each summit. In addition to the meetings of the heads of state and government, specialist ministerial meetings are also held under each presidency, including meetings of the climate protection and energy ministers. The G7 presidency rotates annually between the members. Japan took over the presidency from Germany in 2023. As a member of the G7, Germany, working together with other members, strives to find solutions to global challenges and contribute to shaping a sustainable and just world. Germany's main goals in the G7 include

- promotion of climate protection (reduction of greenhouse gas emissions, expansion of renewable energy, strategies for adaptation to climate change),
- strengthening of sustainable development (promoting sustainable production and consumption, combating poverty and social inequality, improving resource efficiency),
- promotion of free and fair trade (dismantling trade barriers, fair conditions of competition, strengthening international trade rules),
- close cooperation on global challenges (health security, support for developing countries, resolution of international conflicts)
- promotion of education and innovation (ensuring quality education, advancing digitalisation, cooperation in research and development).

The ‚Group of Twenty' (G20) includes the 19 most important industrialised and emerging countries and the European Union. It has existed since 1999 and is the most important forum for international governance and regulation. The G20 countries currently represent just over 80% of global gross domestic product (GDP) and global CO_2 emissions, three quarters of world trade and around two thirds of the world's population.

The G20 is the central forum for international co-operation on financial and economic issues. Energy policy issues have become increasingly important here. In addition to the meetings of the heads of state and government, specialist ministerial meetings are held under each presidency, as is the case with the G7. These include meetings of the climate protection, environment and energy ministers. The G7 presidency rotates annually between members. India holds the presidency in 2023, having taken over from Indonesia (2022).

Renewable Energy Policy Network for the 21st Century – REN21

The first worldwide International Renewable Energy Conference "renewables2004" which took place in Bonn and was initiated by the German government, put the topic of renewable energy sources on the global agenda. The conference provided crucial momentum: the more than 100 participating countries acknowledged that renewable energy would play a key role in a future energy system and at the same time committed themselves to national or regional targets and measures. In order to continue the momentum, the network REN21 – Renewable Energy Policy Network for the 21st Century – was subsequently founded, which in the meantime gives decisive impetus to the political debates on renewable energy with its annual Global Status Report [43].

REN21 has in the meantime developed into an important global multi-stakeholder network. It plays a central role in providing conceptual and organisational support to the host countries of the IRECs (International Renewable Energy Conferences). Government agencies, international organisations, civil society, science and the private sector from the energy, environment and development sectors are represented in the network. The German government is represented in the 'Bureau', the executive body of the network, 2022 – 24 by the BMWK and the Federal Ministry for Economic Cooperation and Development (BMZ).

REN21 annually publishes the 'Global Renewable Energy Status Report' (GSR), which tracks the annual expansion of renewable energy worldwide and has established itself as the network's flagship publication. The report presents the status and geographical distribution of installed renewable energy installations worldwide, expansion targets and policy instruments as well as global investments in renewable energy [43].

In addition to the Global Status Report, REN21 publishes further reports with different focuses and regional status reports that analyse the development of renewable energy sources in individual regions of the world in greater depth.

International Renewable Energy Conferences (IRECs)

The great success of "renewables2004" was continued by the International Renewable Energy Conferences (IRECs). The individual conferences have each provided strong political impetus for the accelerated expansion of renewable energy worldwide. At the same time, the IREC conferences often had a major impact in the respective host country. After 2004, there were follow-up conferences in China, the USA, India, the United Arab Emirates, Mexico, South Korea and most recently in Spain.

The next International Renewable Energy Conference, AUSIREC 2024, will take place from 7 – 11 April 2024 in Adelaide, Australia. AUSIREC will be the first IREC conference in Oceania. A particular focus will be placed on regional participation, especially from the Pacific island states.

Berlin Energy Transition Dialogue – BETD

Since 2015, the BMWK, the Federal Foreign Office (AA), the German Renewable Energy Federation (BEE), the German Solar Industry Association (BSW Solar), the German Energy Agency (dena) and eclareon have organised an international energy transition conference, the "Berlin Energy Transition Dialogue", every spring. The two-day conference serves to intensify the international exchange of experiences, challenges and opportunities of the global energy transition.

In 2023, under the motto "Energy Transition – Securing a Green Future", ministers and high-level delegations from over 60 countries discussed strategies for the intelligent transformation of energy systems worldwide and towards climate neutrality with representatives from business, science and civil society. In addition, several bilateral agreements were adopted to deepen existing partnerships and establish new climate and energy alliances between Germany and other partner countries such as Chile and Uruguay.

Clean Energy Ministerial – CEM

The Clean Energy Ministerial (CEM) is a global forum founded in 2010 to promote a sustainable global energy supply, in which 28 industrialised and emerging countries as well as the European Union participate. Most recently, Poland and Portugal joined at the 12th CEM Ministerial Meeting in early June 2021.

The core of the CEM is the cooperation of the member countries, mostly organised on a technology-specific basis, in various initiatives as well as in short-term so-called campaigns that also include actors from the private sector and civil society. This cooperation goes back to ten technology action plans on a range of low-carbon technologies that were jointly developed by a number of industrialised countries in 2009 in preparation for the COP 15 climate conference in Copenhagen.

Germany, represented by the BMWK, leads the multilateral initiative on long-term scenarios for the energy transition and the Investment and Finance Initiative together with Denmark, among others. New priorities for the work of the initiatives are decided at annual conferences at the ministerial level.

In July 2023, the 14th CEM Ministerial Meeting was held in Goa, India with the main focus on clean energy, clean transport, clean industry, clean buildings, clean solutions and empowerment of society.

Mission Innovation – MI

Mission Innovation is a global initiative of 24 countries and the European Union working to promote the easy and affordable availability of clean energy technologies for all.

MI was established at the United Nations Climate Change Conference in Paris in 2015 by the heads of state and government gathered there to support the fight against climate change. The intergovernmental initiative focuses in particular on higher public and private sector investment. The member countries have committed to implementing over 220 pilot projects by 2030 to accelerate the energy transition. The MI Ministerial Meetings are typically held after the CEM meetings at the same location, most recently in July 2023 in Goa, India.

In 2021, Mission Innovation entered its second phase (MI 2.0), which is organised into seven missions. As part of MI 2.0, Germany has focused on the global topic of hydrogen and is therefore involved in the "Clean Hydrogen Mission". Germany is also involved in the Green Powered Future Mission, the Zero-Emission Shipping Mission and the Net-Zero Industries Mission. Other missions include the Carbon Dioxide Removal Mission, the Urban Transitions Mission and the Integrated Biorefineries Mission. Germany is also involved in the Innovation Platform Materials for Energy.

The International Solar Alliance (ISA)

Based on an initiative by India in close cooperation with France at the 2015 Paris Climate Conference (COP21), the International Solar Alliance (ISA) was founded in 2017 with headquarters in New Delhi. According to the agreement, the member states established the ISA to mobilise investments in solar energy and to accelerate the expansion of solar energy generation capacities in the member countries. Solar energy is expected to meet energy needs while promoting prosperity, energy security and sustainable development. The ISA will act as a focal point for solar energy, providing networks and advice to support the development of solar energy ('on the ground').

In autumn 2021, after the geographical restriction to 'states and territories between the two tropics' was dropped, Germany, among others, was able to join the ISA, so that the organisation now has over 100 members. The ISA is led by its Director General, Dr Ajay Mathur an Indian elected for a four-year term.

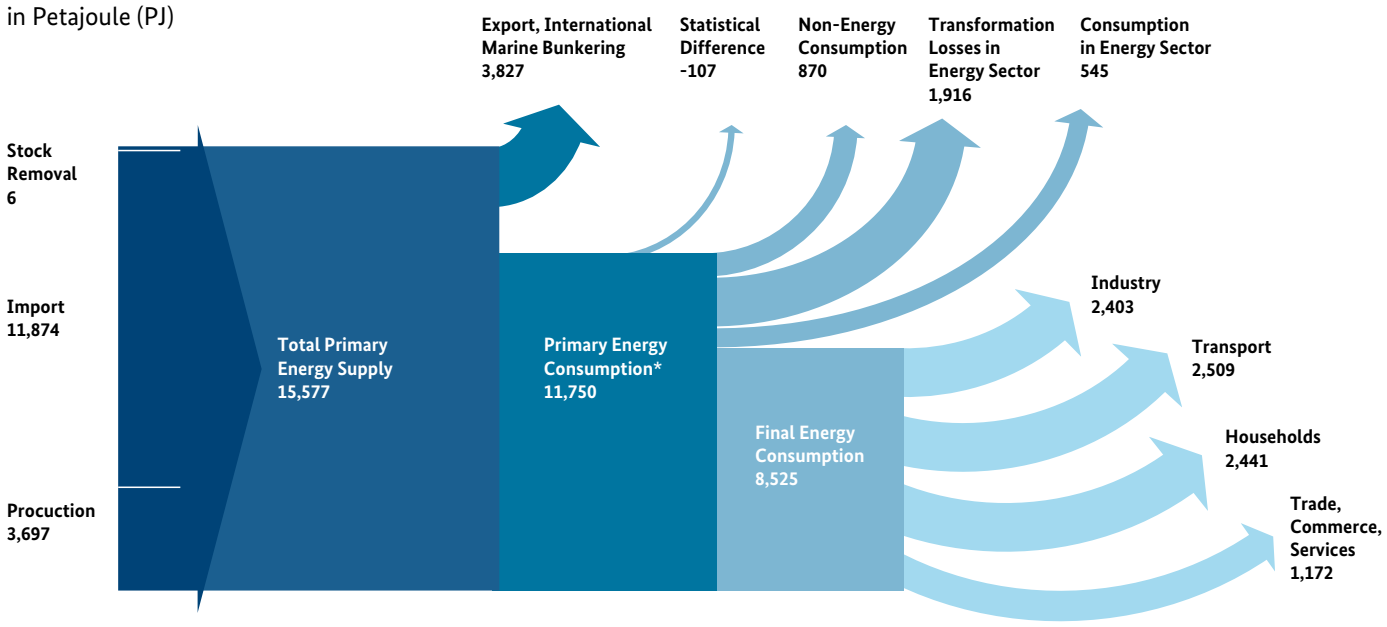
Information on methodology

Some of the figures published in this report are provisional. Where the final data are published, they may differ from previous publications. Differences between the figures in the tables and the respective column or row totals are due to rounding. The terminology commonly used in energy statistics includes the term (primary) energy consumption. This is not strictly correct from a physical point of view, however, because energy cannot be created or consumed, but merely converted from one form to another (e.g. heat, electricity, mechanical energy). This process is not entirely reversible, however, meaning that a portion of the energy's exergy is lost.

For more information on the German terminology used in energy statistics, please refer to the BMWK website Glossar Energiewende (Energy Transition Glossary, in German only).

The amounts of energy (gross electricity consumption, final energy consumption from renewables for heating and cooling and for transport) presented in this brochure cannot be properly added to produce an aggregate value because they are determined on the basis of specific conventions, which differ in each case. Thus, no share of total final energy consumption can be calculated on this basis.

Figure 58: Energy Flow Chart for Germany, 2022



* Deviations from the total amounts are due to rounding. The total proportion of renewable energy sources of the primary energy consumption is 17.6%.

Source: Working Group on Energy Balances (AG Energiebilanzen) 09/2023

Methodological changes

AGEE-Stat is continuously working on methodological improvements to renewable energy sources statistics. In technical discussions and through the exchange of experts on individual renewable energy sources, new insights are continuously being gained to improve the data basis of electricity generation and heat supply from renewable energy sources. The methodological changes derived from this aim to ensure the long-term updating of renewable energy sources statistics and at the same time to create a uniform data basis for the fulfilment of national and international reporting obligations. An overview of the current methodological changes is provided below:

New data source for grid feed-in as part of the balancing of gross and net electricity generation from renewable energy as of 2021

The time series for gross and net electricity generation from renewable energy sources were previously based, among other things, on the transaction data collected as part of annual billing in accordance with the Renewable Energy Sources Act (RES) and supplemented by self-consumption of own generation (economic self-consumption) as well as technical self-consumption. Because as of 2021 a steadily increasing number of plants reached their maximum subsidy period and ever more power plants began marketing a portion of their electricity outside of the RES, a reorganisation of the grid feed-in database became necessary. As of 2021 AGEE-Stat will therefore use the official data from the Federal Statistical Office's "Survey on electricity feed-in and feed-out by grid operators" (066N) as a data source for the quantities of electricity fed into the public grid, supplemented where necessary by self-consumed own generation (economic self-consumption) and technical self-consumption. These statistics include the quantities of electricity fed in by all generation plants connected to the public electricity grid, regardless of the size of the plant or the form of subsidisation or marketing.

Additionally, the calculation of electricity based on biogas, biomethane and solid and liquid biomass was further refined and brought up to date. In this way, transformer and line losses as well as economic self-consumption are considered. For biogas plants, the company's own consumption (for pumps, agitators, etc.) is also now considered, provided it comes from the company's own electricity generation. When accounting for electricity generation from solid biomass, official surveys are used to a greater extent than before, supplemented by estimates of technical self-consumption and economic self-consumption of plants < 1 MW electrical output.

Update of the methodology for recording the provision of heat from heat pumps

The methodology for recording near-surface geothermal energy and ambient heat was updated on the basis of scientific recommendations and following consultation with industry experts at an AGEE-Stat expert meeting. Among other things, varying service life curves for air-to-water and brine-to-water/water-to-water heat pumps were implemented in the model. In addition, past time series on sales of electric heating heat pumps were slightly updated and adjusted where the heat source could not be clearly identified as renewable. Other model parameters for average output and efficiency were assessed as plausible by industry experts and retained.

Calculations according to the Renewable Energy Directives (RED I and II)

The Renewable Energy Directive (2009/28/EC) has been the foundation for European renewable energy policy since 2009. It has served as the basis for the assessment and promotion of renewable energy in the European Union. The original directive was comprehensively amended with effect from December 2018 by Directive 2018/2001/EC (RED II), which came into force in 2021.

For the calculation of target achievement, the EU Directive on the promotion of the use of energy from renewable sources contains detailed specifi-

cations in Article 7. In addition to the overall share of renewable energy sources in gross final energy consumption, sectoral shares are also determined in the sub-sectors of electricity, heat and transport.

Gross final energy consumption is the basis for the binding national target values within the RED and is defined in Directive 2018/2001/EC in Article 2 No. 4 as follows:

"'Gross final consumption of energy' means the energy commodities delivered for energy purposes to industry, the transport sector, households, the services sector, including the public services sector and the agriculture, forestry and fisheries sectors, the electricity and heat consumed by the energy sector in the production of electricity, heat and transport fuels, and the electricity and heat losses occurring during distribution and transmission."

A comparison of the data reported according to the requirements of the EU Directive with statistics from other sources, such as the data on the Renewable Energy Sources Act or the national energy statistics, is only possible to a limited extent because specific methodological requirements are partly applied in the reporting on the EU Directive. Among other things, fluctuations in electricity yields due to weather conditions are adjusted when calculating the contributions from wind and hydropower. Through this 'normalisation' to an average year, the value for wind and hydropower no longer corresponds to the actual yield of the corresponding year, but better reflects the targeted expansion of renewable electricity generation capacities.

Furthermore, bioenergy sources and biofuels must meet certain sustainability criteria in order to count towards the targets set out in the EU directive.

In the transport sector, the contribution of electricity from renewable sources is boosted through multiple crediting when used in road and rail transport. In addition, biofuels produced from raw and residual materials according to Annex IX of the Directive are counted twice towards the share of renewable energy sources in the transport sector.

Calculation of the share without applying the calculation method according to the EU Directive

The share of renewable energy sources in gross final energy consumption was also included as a target in the German government's 2010 energy concept. In line with the EU Directive, Germany aimed for an 18% share of renewables in 2020. However, the calculation method used to reflect the development of renewable energy deviates from that of the EU Directive in that the share of gross final energy consumption is mapped with the real generation of wind and hydropower as well as the actual consumption of biofuels in the transport sector.

Economic impulses from the use of renewable energy sources

The expansion of renewable energy sources in Germany in recent years has led to a further increase in the importance of the renewable energy sector for the economy as a whole. The construction of renewable energy plants for the utilisation of electricity and heat contributes to this. Additionally, due to the increasing number of plants, the operation of these plants represents a growing economic factor.

The investments made in renewable energy systems are determined on the basis of the capacity added or the number of systems. With the help of specific investment costs (€/kW) or average costs per plant (€/plant), the total investments per sector in the year under consideration are calculated. For plants with a construction period of several years, the investments are allocated on an accrual basis. This applies to offshore wind-powered installations, deep geothermal plants and large hydropower plants, but also to large biomass cogeneration plants and biogas plants. In this way, investments are not just attributed to the year of plant completion or commissioning.

In addition to the expenses for operating and maintenance of the plants, especially in the form of personnel costs, the provision of renewable fuels and biofuels also contributes to the economic impulses from plant operation.

The costs for maintenance and operation of the plants are determined on the basis of technology-specific valuations. Cost calculations from various scientific studies were used for this purpose. These include most importantly the research projects on the RES (especially the research reports on the RES experience report, e.g. [46], the evaluations of the Market Incentive Programme (e.g. [47]), and the evaluations of KfW funding for renewable energy sources [48].

To determine the costs of fuel supply for electricity and heat generation, the costs of solid and liquid fuels as well as the substrates used to produce biogas are taken into account. The relevant solid biomass fuels primarily include waste wood, forest and industrial waste wood, wood pellets, wood chips, wood briquettes and the commercially traded part of firewood. The main components of substrates for biogas production are maize silage, grass silage, and whole-plant cereal silage and minor cereals. Overall, the economic impulses from the provision of biogenic fuels were valued at €6.3 billion.

Conversion factors

Metric prefixes							
Megawatt hour:	1 MWh = 1,000 kWh	Kilo	k	10^{3*}	Tera	T	10^{12}
Gigawatt hour:	1 GWh = 1 million. kWh	Mega	M	10^{6}	Peta	P	10^{15}
Terawatt hour:	1 TWh = 1 million kWh	Giga	G	10^{9}	Exa	E	10^{18}

Units of energy and output	
Joule J	for energy, work, heat quantity
Watt W	for power, energy flux, heat flux
1 Joule (J) = 1 Newton metre (Nm) = 1 Watt second (Ws)	

Legally binding units in Germany since 1978. The colorle and derived units such as coal equivalent and oil equivalent are still used as alternatives.

Conversion factors					
		PJ	TWh	Mzce	Mtoe
1 Petajoule	PJ	1	0.2778	0.0341	0.0239
1 Terawatt hour	TWh	3.6	1	0.123	0.0861
1 million tonnes coal equivalent	Mtce	29.308	8.14	1	0.7
1 million tonnes crude oil equivalent	Mtoe	41.869	11.63	1.429	1

The figures refer to the heat calorific value.

Grenhouse gases	
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
SF_6	Sulphur hexafluoride
H-FKW	Hydrofluorocarbons
FKW	Perfluorocarbons

Other air pollutants	
SO_2	Sulphur dioxide
NO_X	Nitrogen oxides
HCI	Hydrogen chloride (Hydrochloric acid)
HF	Hydrogen fluoride (Hydrofluoric acid)
CO	Carbon monoxide
NMVOC	Non-methane volatile organic compounds

* 10^2 = 100, 10^3 = 1,000, 10^4 = 10,000, 10^5 = 100,000, 10^6 = 1,000,000 etc.

List of abbreviations

ACEA	European Automobile Manufacturers' Association (Association des Constructeurs Européens d'Automobiles)
AGEB	Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen e.V.)
AGEE-Stat	Working Group on Renewable Energy Statistics (Arbeitsgruppe Erneuerbare Energien-Statistik)
BAFA	Federal Office for Economic Affairs and Export Control (Bundesamt für Wirtschaft und Ausfuhrkontrolle)
BAW	Federal funding development program (Bundesförderung Aufbauprogramm)
BEG	Federal Funding for Efficient Buildings (Bundesförderung für effiziente Gebäude)
BETD	Berlin Energy Transition Dialogue
BEV	Battery electric vehicle
BDEW	German Association of Energy and Water Industries (Bundesverband der Energie- und Wasserwirtschaft)
BDH	Federation of German Heating Industry (Bundesverband der deutschen Heizungsindustrie)
BEW	Federal funding for efficient heating networks (Bundesförderung für effiziente Wärmenetze)
BLE	Federal Office for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung)
BImSchG	Federal Immission Control Act (Bundes-Immissionsschutzgesetz)
BImSchV	Ordinance for the implementation of the Federal Immission Control Act (Verordnung zur Durchführung des Bundes-Immissionsschutzgesetzes)
BMBF	Federal Ministry of Education and Research (Bundesministerium für Bildung und Forschung)
BMEL	Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz)
BMDV	Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr)
BMWK	Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz)
BMWSB	Federal Ministry of Housing, Urban Development and Building (Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen)
BMZ	Federal Ministry for Economic Cooperation and Development (Bundesministerium für wirtschaftliche Zusammenarbeit)
BNatSchG	Federal Nature Conservation Act (Bundesnaturschutzgesetz)
BNetzA	Federal Network Agency (Bundesnetzagentur)
BReg	The Federal Government (Bundesregierung)
BRICS	Brazil, Russia, India, China, South Africa
BSW	German Solar Association (Bundesverband Solarwirtschaft)
BTX	Bio-to-X, Bio2X refers to technologies for converting biomass into electricity and heat.
BWP	German Heat Pumps Association (Bundesverband Wärmepumpe e.V.)
CHP	Combined heat and power plant
CERT	Committee on Energy Research and Technology
CEM	Clean Energy Ministerial
CNG	Compressed natural gas

COP-XX	UN Conference for the Convention on Biological Diversity (for example: Fifteenth meeting of the Conference of the Parties to the Convention on Biological Diversity (COP15))
CO_2-eq.	CO_2-equivalent
DBFZ	German Biomass Research Centre Leipzig (Deutsches Biomasseforschungszentrum)
DEPV	German Wood and Pellet Fuel Association (Deutscher Energieholz- und Pellet-Verband e.V.)
dena	German Energy Agency (Deutsche Energie-Agentur)
DIW Berlin	German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung)
DLR	German-Aerospace-Center (Deutsches Zentrum für Luft- und Raumfahrt e.V.)
E-Fuels	Synthetic fuels
EBW	Energy consulting for residential buildings (Energieberatung für Wohngebäude)
ECN	Energy research Centre of the Netherlands
EEWärmeG	Renewable Energies Heat Act (Erneuerbare-Energien-Wärme-Gesetz)
EKF	Energy and Climate Fund (Energie- und Klimafonds)
EM	Individual Measures (Einzelmaßnahmen)
EnEG	Energy Conservation Act (Energieeinsparungsgesetz)
EnEV	Energy Saving Ordinance (Energieeinsparverordnung)
EnUG	Energy Allocation Act (Energie-Umlagen-Gesetz)
EnWG	Energy Industry Act (Energiewirtschaftsgesetz)
EU	European Union
Eurostat	Statistical Office of the European Union
ENTSO-E	Association of European Transmission System Operators
EU	European Union
Eurostat	Statistical Office of the European Union
ESTIF	European Solar Thermal Industry Federation
EWEA	European Wind Energy Association
Fh-ISE	Fraunhofer Institute for Solar Energy Systems ISE
FEC	Final energy consumption
FNR	Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V.)
GDP	Gross domestic product
GHG	Greenhouse gas
GEG	Buildings Energy Act (Gebäudeenergiegesetz)
GeotIS	Geothermal information system (Geothermische Informationssystem)
GSR	Global Status Report
GWh	Gigawatt hours
GWP	Global warming potential
GWS	The Institute of Economic Structures Research (Gesellschaft für wirtschaftliche Strukturforschung)
GZB	Internationale Geothermiezentrum
HIC	Hamburg Institute
HH	Households
HP	Heating plant
HVO	Hydrotreated Vegetable Oil
IE Leipzig	Leipzig Institute for Energy
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
ISA	International Solar Alliance
IPCEIs	Important Projects of Common European Interest
IRECs	International Renewable Energy Conferences
KBA	Federal Motor Transport Authority (Kraftfahrt-Bundesamt)

KfW	KfW (Kreditanstalt für Wiederaufbau)
KWKG	Combined Heat and Power Act (Kraft-Wärme-Kopplungsgesetz)
KSG	Federal Climate Change Act (Bundes-Klimaschutzgesetz)
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
LSV	Charging Station Ordinance (Ladesäulenverordnung)
MaStR	Core Energy Market Data Register (Marktstammdatenregister)
MaStRV	Core Energy Market Data Register Ordinance (Marktstammdatenregister)
MAP	Market Incentive Programme (MAP)
NABEG	Grid Expansion Acceleration Act (Netzausbaubeschleunigungsgesetz Übertragungsnetz)
NECP	National Energy and Climate Plan
NREAP	National Renewable Energy Action Plan
NUTS 2	Definition of regions for regional policy measures
NWG	Non-residential buildings (Nichtwohngebäude)
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaics
PEC	Primary energy consumption
PHEV	Plug-in-hybrid Electric Vehicle
ptj	Project management agency (Projektträger Jülich)
PP	Power plans
PTX	Power-to-X
RES	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
RED	Renewable Energy Directive
R&D	Research and development
RE/RES	Renewable energy (sources)
REN 21	Renewable Energy Policy Network for the 21st Century
REWP	Renewable Energy Working Party
RFNBO	Product group of renewable fuels within the meaning of the Renewable Energy Directive (Article 2 Number 36) (Produktgruppe erneuerbarer Brenn- bzw. Kraftstoffe im Sinne der Erneuerbare Energien-Richtlinie (Artikel 2 Nummer 36))
SEforALL	Sustainable Energy for All Initiative
SMARD	Electricity market data: information platform of the Federal Network Agency (Strommarktdaten)
StBA	Federal Statistical Office (Statistisches Bundesamt)
StromEinspG	Act on the Sale of Electricity to the Grid (Stromeinspeisungsgesetz)
SystEEm	Integration of renewable energy sources and regenerative energy supply systems
TCP	Technology Collaboration Programmes
TCS	Trade, commerce and service sector
TSO	Transmission system operator
UBA	Federal Environment Agency (Umweltbundesamt)
UFOP	Union for the Promotion of Oil and Protein Plants e.V.
UL	UL International GmbH
USD	United States Dollars
VDEW	Association of the Electricity Industry (Verband der Elektrizitätswirtschaft e.V.)
WHO	World Health Organization
WindBG	Wind Energy Area Requirements Act (Windenergieflächenbedarfsgesetz)
WindSeeG	Offshore Wind Energy Act (Windenergie-auf-See-Gesetz)
WG	Residential building (Wohngebäude)
WPG	Heat planning law (Wärmeplanungsgesetz)
ZSW	Centre for Solar Energy and Hydrogen Research (Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg)

List of sources

[1] Richtlinie (EU) 2018/2001 des Europäischen Parlaments und des Rates vom 11. Dezember 2018 zur Förderung der Nutzung von Energie aus erneuerbaren Quellen (Text von Bedeutung für den EWR.) (Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance.), 2018. Accessed on: 11. August 2023. Available at: http://data.europa.eu/eli/dir/2018/2001/oj/deu

[2] Bundesregierung (BReg) [Federal Government], Gesetz zu Sofortmaßnahmen für einen beschleunigten Ausbau der erneuerbaren Energien und weiteren Maßnahmen im Stromsektor (EEG 2023) (Law on emergency measures for an accelerated expansion of renewable energies and other measures in the electricity sector, (EEG 2023)) Bd. 1237. 2022. [Online]. Available at: https://www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl122s1237.pdf#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl122s1237.pdf%27%5D__1698050984449

[3] Bundeministerium für Wirtschaft und Klimaschutz (BMWK) [Federal Ministry for Economic Affairs and Climate Action], "Zeitreihen Erneuerbare Energien" (Time Series Renewable Energy Sources), Available at: www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Zeitreihen/zeitreihen.html

[4] Deutscher Energieholz-und Pellet-Verband e.V. (DEPV), "Pelletfeuerungen". Accessed on: 31. Juli 2023. [Online]. Available at: https://www.depv.de/pelletfeuerungen

[5] AG Energiebilanzen [Working Group on Energy Balances], "AG Energiebilanzen e.V. Balances 1990 – 2030" (Working Group on Energy Balances | Balances 1990 – 2030 Available at: https://ag-energiebilanzen.de/daten-und-fakten/bilanzen-1990-bis-2030/

[6] Umweltbundesamt (UBA) [German Environment Agency], Emissionsbilanz erneuerbarer Energieträger. (Emissions balance of renewable energy sources). October 2022. Available at: www.umweltbundesamt.de/publikationen/emissionsbilanz-erneuerbarer-energietraeger

[7] Arbeitsgemeinschaft Energiebilanzen (AGEB) [Working Group on Energy Balances], "Heizwerte der Energieträger und Faktoren für die Umrechnung von spezifischen Mengeneinheiten in Wärmeeinheiten (2005 – 2021)" (Calorific values of energy sources and factors for the conversion of specific units of measure to heat units, 2005 – 2021), 08. Februar 2023. Accessed on: 31. Juli 2023. [Online]. Available at: www.ag-energiebilanzen.de

[8] Gesetz für den Ausbau erneuerbarer Energien (Erneuerbare-Energien-Gesetz – EEG 2023) (Renewable Energy Act – EEG 2023)) Accessed on: 2. October 2023. [Online]. Available at: https://www.gesetze-im-internet.de/eeg_2014/inhalts_bersicht.html

[9] Bundesregierung (BReg) [Federal Government], Gesetz zur Erhöhung und Beschleunigung des Ausbaus von Windenergieanlagen an Land (Onshore Wind Energy Act), Bd. 1353. 2022. [Online]. Available at: www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl122s1353.pdf

[10] Bundesregierung (BReg) [Federal Government], Zweites Gesetz zur Änderung des Windenergie-auf-See-Gesetzes und anderer Vorschriften (WindSeeG) (Second Act Amending the Wind Energy at Sea Act and Other Regulations (WindSeeG)), Bd. 1353. [Online]. Available at: www.bgbl.de/xaver/bgbl/start.xav?startbk=Bundesanzeiger_BGBl&jumpTo=bgbl122s1325.pdf

[11] BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. [Association of Energy and Water Industries], "BDEW-Strompreisanalyse Juli 2023" (BDEW electricity price analysis July 2023), Accessed on: 3. August 2023. [Online], Available at: www.bdew.de/service/daten-und-grafiken/bdew-strompreisanalyse/

[12] D. Ritter, D. Seebach, M. Haller (Öko-Institut) J. Bogner, M. Claußner, F. Huneke (Energy Brainpool), "Monitoring der Direktvermarktung: Jahresbericht 2022 & Ausblick 2023", (Monitoring of direct marketing: Annual report 2022 & outlook 2023) März 2023. Accessed on: 11. July 2023. [Online]. Available at: https://www.erneuerbare-energien.de/EE/Redaktion/DE/Downloads/Berichte/monitoring-der-direktvermarktung-quartalsbericht-03-2022.html

[13] Informationsplattform der deutschen Übertragungsnetzbetreiber [Information platform of the German Transmission System Operators], "Jahresabrechnungen nach dem Erneuerbare- Energien-Gesetz (EEG-Jahresabrechnungen 2000 – 2022)" (Renewable energy sources Act annual accounts 2000 – 2022), Accessed on: August 2023. Available at: www.netztransparenz.de

[14] P. Lewicki, "Photovoltaik" (Photovoltaics), Umweltbundesamt. Accessed on: 13. September 2023. [Online]. Available at: https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/photovoltaik

[15] Bundesministerium für Wirtschaft und Klimaschutz (BMWK) [Federal Ministry for Economic Affairs and Climate Action], "Mit der Kraft der Sonne: Entwurf Solarpaket I". Accessed on: 16. August 2023. [Online]. Available at: https://www.bmwk.de/Redaktion/DE/Dossier/Energieversorgung/details-solarpaket-1.html

[16] Bundesministerium für Wirtschaft und Klimaschutz (BMWK) [Federal Ministry for Economic Affairs and Climate Action], "Photovoltaik-Strategie",Mai 2023 ("Photovoltaic strategy", Mai 2023). Accessed on: 15. June 2023. [Online]. Available at: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/photovoltaik-stategie-2023.html

[17] GWS, "Ökonomische Indikatoren des Energiesystems Methode, Abgrenzung und Ergebnisse für den Zeitraum 2000 – 2016" (Economic energy system indicators: method, definition and results for 2000 – 2016). GWS Research Report 2018/02", Osnabrück, February 2018.

[18] DIW, DLR, GWS, "Ergebnisse aus dem laufenden Forschungsvorhaben ‚Ökonomische Indikatoren des Energiesystems' im Auftrag des BMWi" (Results from the ongoing research project 'Economic indicators of the energy system' on behalf of the BMWi), Mai 2022.

[19] Umweltbundesamt (UBA) [Federal Environment Agency], "Energieverbrauch für fossile und erneuerbare Wärme" (Energy consumption for fossil and renewable heat), Umweltbundesamt. Available at: www.umweltbundesamt.de/daten/energie/energieverbrauch-fuer-fossile-erneuerbare-waerme

[20] Umweltbundesamt (UBA) [Federal Environment Agency], "Treibhausgasminderungsziele Deutschlands" (Germany's greenhouse gas reduction targets), Accessed on: 03. August 2023. [Online]. Available at: www.umweltbundesamt.de/daten/klima/treibhausgasminderungsziele-deutschlands

[21] Bundeministerium für Wirtschaft und Klimaschutz (BMWK) [Federal Ministry for Economic Affairs and Climate Action], "BEG-Reporting". Accessed on: 2. October 2023. [Online]. Available at: https://www.energiewechsel.de/KAENEF/Redaktion/DE/Meldungen/2023/20230321-neues-beg-reporting-veroeffentlicht.html

[22] Bundesministerium für Wirtschaft Klimaschutz (BMWK) [Federal Ministry for Economic Affairs and Climate Action] and Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen (BMWSB) [Federal Ministry of Housing, Urban Development and Building,] "Breites Bündnis für mehr Tempo beim Aus- und Umbau der Wärmenetze" (Broad alliance for more speed in the expansion and conversion of heating networks). Accessed on: 8. August 2023. [Online]. Available at: https://www.bmwk.de/Redaktion/DE/Pressemitteilungen/2023/06/20230612-aus-und-umbau-waermenetze.html

[23] M. Lambrecht, "Klimaschutz im Verkehr" (Climate protection in transport), Umweltbundesamt (UBA) [Federal Environment Agency]. Accessed on: 22. June 2023. [Online]. Available at: https://www.umweltbundesamt.de/themen/verkehr/klimaschutz-im-verkehr

[24] Kraftfahrt-Bundesamt (KBA) [Federal Motor Transport Authority], "Kraftfahrt-Bundesamt – Neuzulassungen an Kraftfahrzeugen 2022" (Federal Motor Transport Authority – new vehicle registrations 2022). Accessed on: 3. August 2023. [Online]. Available at: https://www.kba.de/DE/Statistik/Fahrzeuge/Neuzulassungen/Jahresbilanz_Neuzulassungen/jahresbilanz_node.html

[25] Kraftfahrt-Bundesamt (KBA) [Federal Motor Transport Authority], "Kraftfahrt-Bundesamt – Bestand – Jahresbilanz 2021" (Federal Motor Transport Authority – Stock – Annual balance 2021.) Accessed on: 3. August 2023. [Online]. Available at: https://www.kba.de/DE/Statistik/Fahrzeuge/Bestand/Jahrebilanz_Bestand/fz_b_jahresbilanz_node.html?yearFilter=2022

[26] Bundesnetzagentur (BNetzA) [Federal Network Agency], "Bundesnetzagentur – Elektromobilität: Öffentliche Ladeinfrastruktur" (Federal Network Agency – Electromobility: public charging points infrastructure), Accessed on: 10. July 2023. [Online]. Available at: https://www.bundesnetzagentur.de/DE/Fachthemen/ElektrizitaetundGas/E-Mobilitaet/start.html

[27] Eurostat, Statistics | Eurostat: "Share of renewable energy in gross final energy consumption by sector". Accessed on: 21. August 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_IND_REN/default/table?lang=en

[28] Eurostat, Statistics | Eurostat: "Gross production of electricity and derived heat from non-combustible fuels by type of plant and operator (online data code: NRG_IND_PEHNF)". Accessed on: 21. August 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_IND_PEHNF__custom_7183896/default/table?lang=de

[29] Eurostat, Statistics | Eurostat: "Gross production of electricity and derived heat from combustible fuels by type of plant and operator". Accessed on: 21. August 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_IND_PEHCF__custom_7183680/default/table?lang=de

[30] Eurostat, Statistics | Eurostat: "Imports of electricity and derived heat by partner country". Accessed on: 21. August 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_TI_EH/default/table?lang=de&category=nrg.nrg_quant.nrg_quanta.nrg_t.nrg_ti

[31] Eurostat, Statistics | Eurostat: "Exports of electricity and derived heat by partner country". Accessed on: 21. August 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_TE_EH/default/table?lang=de&category=nrg.nrg_quant.nrg_quanta.nrg_t.nrg_te

[32] Eurostat, Statistisches Amt der Europäischen Gemeinschaften, Luxemburg, "Electricity production capacities for renewables and wastes". Accessed on: 19. July 2022. [Online]. Available at: https://ec.europa.eu/eurostat/de/web/products-datasets/product?code=nrg_inf_epcrw

[33] IRENA, "Renewable Capacity Statsitics 2023", 07 2023. [Online]. Available at: https://www.irena.org/Publications/2023/Jul/Renewable-energy-statistics-2023

[34] EurObserv'ER, "Solar thermal and CSP barometers Archives, 2023", EurObserv'ER. [Online]. Available at: https://www.eurobserv-er.org/category/all-solar-thermal-and-concentrated-solar-power-barometers/

[35] EurObserv'ER, "The state of renewable Energies in Europa, Edition 2022, 21st EurObserv'ER Report", Feb. 2023. Accessed on: 11. September 2023. [Online]. Available at: https://www.eurobserv-er.org/21st-annual-overview-barometer/

[36] ZSW, "Data Service Renewable Energies". Accessed on: 3. August 2023. [Online]. Available at: https://www.zsw-bw.de/en/media-center/data-service.html

[37] European Automobile Manufacturers' Association (ACEA), "Fuel types of new buses: electric 12.7%, diesel 67.3% market share full-year 2022", ACEA – European Automobile Manufacturers' Association. Accessed on: 3. August 2023. [Online]. Available at: https://www.acea.auto/fuel-cv/fuel-types-of-new-buses-electric-12-7-diesel-67-3-market-share-full-year-2022/

[38] Eurostat, Statistics | Eurostat: "Supply, transformation and consumption of renewables and wastes". Accessed on: 11. September 2023. [Online]. Available at: https://ec.europa.eu/eurostat/databrowser/view/NRG_CB_RW__custom_5661552/default/table?lang=de

[39] EurObserv'ER, "Renewable Energy in Transport Barometer". Accessed on: 13. September 2023. [Online]. Available at: https://www.eurobserv-er.org/category/all-res-in-transport-barometer/

[40] Intergovernmental Panel on Climate Change (IPCC), "AR6 Synthesis Report: Climate Change 2023". Accessed on: 11. September 2023. [Online]. Available at: https://www.ipcc.ch/report/ar6/syr/

[41] IRENA, "World Energy Transitions Outlook 2021, 1.5 ° C Pathway", Juli 2021. Accessed on: 19. July 2021. [Online]. Available at: https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/IRENA_World_Energy_Transitions_Outlook_2021.pdf

[42] IEA International Energy Agency, "Global EV Outlook 2023 – Analysis and key findings". Accessed on: 15. August 2023. [Online]. Available at: https://www.iea.org/reports/global-ev-outlook-2023

[43] REN21 – Renewable Energy Policy Network for the 21st Century, Ed., "Renewables 2023, Global Status Report". 14. Juni 2023. Accessed on: 14. Juni 2023. [Online]. Available at: https://www.ren21.net/reports/global-status-report/

[45] IRENA, "Renewable energy and jobs: Annual review 2023". Accessed on: 16. October 2023. [Online]. Available at: https://www.irena.org/Publications/2023/Sep/Renewable-energy-and-jobs-Annual-review-2023

[46] Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) [Centre for Solar Energy and Hydrogen Research Baden Wuerttemberg] et al, "Vorbereitung und Begleitung bei der Erstellung eines Erfahrungsberichts gemäß § 97 EEG, im Auftrag des Bundesministeriums für Wirtschaft und Energie – Teilvorhaben II c: Solare Strahlungsenergie, Abschlussbericht, März 2019." (Preparation and support in the preparation of a progress report in accordance with § 97 EEG, on behalf of the Federal Ministry for Economic Affairs and Energy – Subproject II c: Solar radiation energy, final report, March 2019), March 2019. Available at: www.zsw-bw.de/uploads/media/zsv-boschundpartner-vorbereitungbegleitung-eeg.pdf

[47] Bundesministerium für Wirtschaft und Energie (BMWi) [Federal Ministry for Economic Affairs and Energy], Evaluation des Marktanreizprogramms zur Förderung von Maßnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt im Förderzeitraum 2019 bis 2020 (Evaluation of the Market Incentive Programme to promote measures to use renewable energy in the heating market in the 2019–2020, funding period 2019), 1 December 2021. Available at: https://www.bmwk.de/Redaktion/DE/Evaluationen/Foerdermassnahmen/evaluation-marktanreizprogramms-2019

[48] Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW) [Centre for Solar Energy and Hydrogen Research Baden Wuerttemberg], "Evaluierung der inländischen KfW-Programme zur Förderung Erneuerbarer Energien in den Jahren 2019 und 2020, Gutachten im Auftrag der KfW Bankengruppe" (Evaluation of KfW's domestic programmes to promote renewable energies in 2019 and 2020, expert opinion commissioned by KfW Bankengruppe).