IEA Bioenergy
Technology Collaboration Programme

Implementation of bioenergy in Germany - 2021 update

Country Reports

IEA Bioenergy: 10 2021

This report was prepared from the 2021 IEA World Energy Balances and Renewables Information, combined with data and information provided by the IEA Bioenergy Executive Committee and Task members[1]. Reference is also made to FAOstat and Eurostat data as well as data from national statistics. All individual country reports were reviewed by the national delegates to the IEA Bioenergy Executive Committee, who have approved the content. General background on the approach and definitions can be found in the central introductory report for all country reports.

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HIGHLIGHTS

- Renewables make up 15% of *total energy supply* in Germany in 2019. The renewable energy share in *final energy consumption* is 18%[2]. Around 55% of renewable energy is from biomass.
- Almost half of the land area in Germany is agricultural land, one third is forest land. Germany has favourable geographic and climatic growth conditions, so there is significant potential for agricultural and forestry biomass, as well as from organic waste streams.
- Up to 2010, growth in renewable energy was dominated by bioenergy; after 2012, the growth has mainly been in wind and solar energy.
- About half of the bioenergy consumed in Germany comes from solid biomass. In the past decade there was a consolidation in biomass use for residential heating, while the use of solid biofuels in industry of for heat/power production was fairly stable.
- The role of biogas is substantial (top in the world, expressed per capita), equivalent to 10% of natural gas consumption.
- Germany used to be the world leader in biodiesel and pure plant oil, peaking at 10% of diesel

[1] While data for 2020 are starting to become available at national level, it was decided to consider trends up to 2019 for good comparability and benchmarking between the different IEA Bioenergy member countries. Care should also be taken when using 2020 data for analysing trends as these data are distorted by the COVID19 Pandemic.

[2] The difference between the share of renewables in supply and consumption relates to unused heat from power plants (which is counted in energy supply, but not in final consumption).

consumption in 2007, with a considerable part being applied as pure biofuel. After 2007, the shift has focused to general blending. In the past decade, levels of transport biofuels have stabilized around 5-6%.

- The national Climate Protection Act approved in June 2021 reflects increasing GHG reduction targets of Germany with a climate neutrality by 2045. The current absolute GHG emissions reduction amounts to 41% (compared to 1990 levels)[3]. This amendment provides new impetus to renewable energy sources. The hydrogen economy is one of Germany's key ambitions[4].

COUNTRY PROFILE

Population and land use

Germany is the fourth biggest country in the EU27. It has a total land area of 358 thousand km² and a population of 83 million people, which represents a relatively high population density of 234 persons per km².

With its moderate climate conditions, Germany offers favourable growth conditions. Around half of the land area (46%) is agricultural land, of which about two-thirds are arable land and one-third permanent meadows/pastures; 33% is forest land (of which 29% protected).

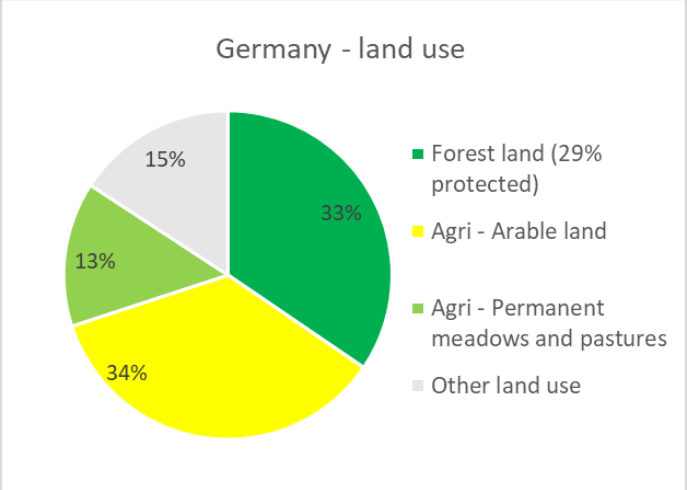

***Figure 1**: Land use in Germany (2018 figures - Source: FAOstat[5])*

Final energy consumption

Overall final energy consumption in Germany (*also including non-energy use of oil, natural gas, and coal in industry*) comes down to 2.7 tonnes of oil equivalent (toe) per capita, which is around the average of IEA Bioenergy member countries. Industry, transport, and residential/services are all around the median of IEA Bioenergy countries. Only non-energy use of fossil resources is a little higher, related to the presence of chemical industries.

[3] https://www.bmwi.de/Redaktion/DE/Artikel/Industrie/klimaschutz-deutsche-klimaschutzpolitik.html
[4] In the German Federal Government's National Hydrogen Strategy of 2020 there is ambiguity on the potential role of biomass for hydrogen which is expected to be clarified by the new government which will come into office after the Sep. 2021 federal elections.
[5] http://www.fao.org/faostat/en/#data/RL

Table 1: Distribution of the final consumption of energy carriers by sector in Germany (2019 figures - Source: IEA (2021) World Energy Balances and Renewables Information)

Final consumption energy carriers	Toe/capita (2019)	% of total	*Median* (toe/capita)*
Industry (energy use)	0.67	25%	*0.67*
Industry (non-energy use)	0.26	10%	*0.21*
Transport	0.68	26%	*0.69*
Residential	0.68	26%	*0.57*
Commercial & public services	0.32	12%	*0.34*
other	0.04	2%	
Total	2.65		*2.34*

** Median of the 25 member countries of IEA Bioenergy*[6]

NATIONAL POLICY FRAMEWORK IN GERMANY

TARGETS AND STRATEGIES

According to its National Energy and Climate Plan for the upcoming decade, Germany has a national target of 30% renewable energy in the gross final energy consumption by 2030. This is in line with the results of the formula under the Governance Regulation on which the Commission bases its assessment of Member States' renewable energy contributions. Moreover, Germany plans for the years 2022, 2025 and 2027 a more ambitious delivery of its national contribution to renewables than the required reference levels.[7] Most recently, in May 2021, the German government amended its Climate Protection Act and agreed on the national 'climate pact' to reach more ambitious targets (cf. Table 2). Germany greenlighted the necessary legal changes to speed up the country's bid for climate neutrality, aiming to meet the target in 2045, instead of 2050. It also has been agreed on a higher GHG-emissions reduction target of 65 percent (previously: 55 percent) by 2030 and a new reduction target of 88 % for 2040, in line with stricter levels of annual emissions for individual sectors (industry, transportation, buildings).

[6] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.

[7] https://ec.europa.eu/energy/sites/ener/files/documents/necp_factsheet_de_final.pdf

Table 2: Renewable energy (RE) and climate targets in Germany.[8,9]

Sector	Share of renewables in gross final consumption per sector	GHG reduction target compared to base year 1990
Overall target	30% in 2030	65% by 2030, 88% by 2040, climate neutrality by 2045[10]
Heating and cooling	15.2 % (2020)	66…67 % by 2030
Electricity	45.4 % (2020)	61…62 % by 2030
Transport	7.3 % (2020)	40…42% by 2030

The corresponding national German Climate Action Plan[11] (passed in 2016) sets the long-term strategy for the development and implementation of the future energy supply in Germany by 2050. Thereby, the concept aims to address a future energy supply that is both secure and affordable while fulfilling the ambitious climate protection targets. At its core it has several policy goals: protecting the climate, increasing energy efficiency and a larger share of renewable energy sources in the final energy consumption, while at the same time promoting the growth and competitiveness of the German industry. An overview of the different targets is provided in Table 3. It defines the measures to be taken in order to achieve the set climate protection target fixed within the Climate Protection Act. Due to the amendment of the German Climate Protection Act in May 2021, the Climate Action Plan needs revision as well. This explains that the figures on the GHG emissions reduction target presented in Table 2 and Table 3 do not correspond.

[8] Climate Action Plan: https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/#c12744

[9] https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

[10] https://www.bundesregierung.de/breg-de/themen/klimaschutz/climate-change-act-2021-1936846

[11] https://www.bmwi.de/Redaktion/DE/Artikel/Industrie/klimaschutz-klimaschutzplan-2050.html https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_kurzf_bf.pdf https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/#c12744 and https://www.bundesregierung.de/breg-de/themen/energiewende

Table 3: German Climate Action Plan: Germany's GHG emission targets, renewable energy, and energy efficiency targets by 2050

"Energy Concept for an Environmentally Sound, Reliable and Affordable Energy Supply" – Targets 2050:

- **60%** of the gross **final energy consumption** from renewable energy sources
- **80%** of the gross **electricity consumption** from renewable energy sources,
- **40% reduction** in gross final energy consumption in the **transport sector** (year of reference 2005)
- **50% reduction** in the total **primary energy consumption** (year of reference 2008)
- **80-95% reduction in GHG-emissions** (year of reference 1990)

The EU Renewable Energy Directive of 2018[12] established an EU-wide binding renewable energy target of 32% by 2030. With the European Green Deal Communication[13] in 2019, the Commission reinforced its climate ambitions, setting an objective of no net emissions of greenhouse gases in 2050. In April 2021, the European Council and the Parliament reached a provisional agreement on the net 55% target for 2030, which sets the ground for the 'fit for 55' legislative proposals scheduled for June 2021.

Electricity

On 29 April 2021, the European Commission approved the prolongation and modification of a German scheme, which is part of the German **Renewable Energy Sources Act** ("Erneuerbare Energien Gesetz" - 'EEG 2021').[14] This scheme supports the production of electricity from renewable energy sources and mine gas. The Renewable Energy Sources Act is the main policy instrument promoting the production of renewable electricity and has been adopted as a feed-in tariff (FIT) system in 2000. With the amendment in 2017, auctions have been introduced for determining the level of remuneration. Hence, most of the future projects are no longer eligible for a statuary feed-in tariff remuneration but will have to bid for onshore wind, offshore wind, solar and biomass projects in public tender procedures. These auctions are organised and monitored by the Federal Network Agency (Bundesnetzagentur). Small-scale biomass installations (up to 150 kW_{el}) are exempted and still eligible to receive feed-in tariffs. Moreover, the EEG provides a premium payment for bioenergy installations that are providing flexibility measures for balancing fluctuating renewable energy sources (flexibility premium). The scheme will help Germany reach its renewable energy targets without unduly distorting competition and will contribute to the EU objective of achieving climate neutrality by 2050. Payments under the scheme for 2021 have been estimated to amount to around €33.1 billion. The difference to the market price for electricity from renewable resources has to be borne by electricity consumers (the EEG surcharge (EEG-Umlage) and a subsidy of the federal

[12] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN
[13] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF
[14] https://www.bmwi.de/Redaktion/EN/Pressemitteilungen/2021/04/20210429-altmaier-european-commission-approves-2021-renewable-energy-sources-act.html

government). The EEG 2021 scheme aims at a share of 65% of electricity produced from renewable energy sources by 2030 (compared to 40% in 2019).[15]

The EEG is supplemented by the **Biomass Ordinance** (Biomasseverordnung – BiomasseV)[16] and the **Biomass Electricity Sustainability Ordinance** (Biomassestrom-Nachhaltigkeitsverordnung – BioSt-NachV)[17] defining criteria and types of biomass that are eligible for receiving support under the EEG. It is noteworthy that the EEG 2021 now excludes electricity from waste (demolition) wood, though the German Parliament voted for an extension until 2026, subject to approval by the EC.

Next to the EEG there is the **Combined Heat and Power Act** (Kraft-Wärme-Kopplung-Gesetz – KWKG)[18] in place. This act aims to increase electricity generation from CHP plants, to support the market introduction of high-efficient fuel cells and funding for construction and expansion of heating and cooling systems. A revision of the Combined Heat and Power Act entered into force on 1 January 2016; in line with this revision, the government has doubled funding for combined heat and power (CHP), raising it to €1.5 billion.

The CHP Act is focusing on (i) combatting climate change, (ii) increasing flexibility, (iii) increasing certainty and predictability for investors, (iv) introducing auctions and (v) harmonising privileges granted under the CHP Act with those granted under the Renewable Energy Sources Act. As an example, the funding scheme for CHP plants will be extended up to 2022, the expansion target will be more clearly defined and further target periods specified (110 TWh of power to be generated from CHP plants by 2020 and 120 TWh of power by 2025).[19]

Heating & Cooling

In the heating/cooling sector, the main policy measures include a financial subsidy through the **Market Incentive Program** (Marktanreizprogramm – MAP)[20], a building regulation in form of the **Renewable Energies Heat Act** (Erneuerbare-Energien-Wärmegesetz – EEWärmeG)[21], as well as further support programs of the public bank KfW[22] and the **Energy Saving Ordinance** (Energieeinsparverordnung – EnEV)[23]. These instruments have allowed for a significant expansion in the use of renewable energies in recent years. The Renewable Energies Heating Act (EEWärmeG)[24] the German Federal government had defined the target of meeting 14% of the heat demand with renewable energy sources by 2020. In fact, renewables' share for heating and cooling purposes has risen from 4.4 percent in 2000 to 15.2 per cent in 2020. Main renewable energy source in this sector remains biomass (solid, liquid, or gaseous), providing still about 85 percent of renewable heat in 2020.[25]

[15] https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2042
[16] https://www.gesetze-im-internet.de/biomassev/BJNR123400001.html
[17] http://www.gesetze-im-internet.de/biost-nachv/BJNR217400009.html
[18] https://www.gesetze-im-internet.de/kwkg_2016/BJNR249810015.html
[19] https://www.bmwi.de/Redaktion/EN/Artikel/Energy/modern-power-plant-technologies.html
[20] http://www.bmwi.de/EN/Topics/Energy/Buildings/market-incentive-programme,did=707926.html
[21] http://www.gesetze-im-internet.de/eew_rmeg/index.html
[22] https://www.kfw.de/inlandsfoerderung/Unternehmen/Energie-Umwelt/Erneuerbare-Energien/
[23] http://www.gesetze-im-internet.de/enev_2007/index.html
[24] https://dejure.org/gesetze/EEWaermeG
[25] https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

The transformation of district heating to higher percentages of renewable energy can contribute to achieving the targets set for 2030 and 2050. The purpose of the act is to promote renewable energies in the heat sector to achieve a sound management of fossil resources and lower dependency on energy imports. The EEWärmeG aims to facilitate a sustainable development of energy supply and further development of technologies generating heat from renewable energy sources.

Transport sector

In 2006, the **Biofuel Quota Act** (BioKraftQuG) and the act to introduce a biofuel quota by amending the **Federal Immission Control Act** (BImSchG) were passed. The BImSchG defined and prescribed for the first time a minimum share of biofuels in total transportation fuel sales in Germany. On European level, one of the key instruments for promoting the use of renewable energy sources in transport is the Renewable Energy Directive (2009/28/EC, RED). The core of this directive is the minimum shares of alternative and renewable energy sources to be achieved by the EU member states (RED: 10% by 2020). In addition, requirements for demonstrating the sustainability and GHG emissions reduction of these energy sources are defined.[26]

In context with the implementation of §17 of the 29-point Integrated Energy and Climate Programme (IECP)27 of the German government, the federal cabinet approved a national ordinance on requirements regarding the sustainable generation of biomass to be applied as biofuel. The Biomass Sustainability Ordinance (BioNachV, 2009) defines minimum sustainability requirements for biomass used for the generation of biofuels. Hence, this ordinance accompanies and supplements the Biofuel Quota Act.

Today, with regard to the overall set targets to significantly reduce GHG emissions on EU and national levels (e.g., by the European Green Deal[28], National Climate and Energy Plan 2050 [NECP][29]), the transition toward decarbonization in the transport sector is ongoing. Germany has committed to reduce its emissions in non-ETS sectors, including the transport sector, by 38% by 2030, compared to 2005 levels, as set in the Effort Sharing Regulation (ESR).[30] Although Germany has already taken comprehensive climate measures, further national efforts are required to achieve the set goal of CO_2 savings.

The measures for GHG emission targets are specified in the Climate Action Programme 2030.[31] With the Climate Action Plan[32], Germany sets a binding target saving of at least 40-42% of GHG emission, compared to 1990, in the transport sector. This translates to 98 to 95 Mt CO_{2eq} in 2030.[33] In total, the government foresees to invest more than €54 billion in climate protection by 2023.

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[26] Naumann K, Müller-Langer F, Meisel K, Majer S, Schröder J, Schmieder U (2021): Weiterentwicklung der deutschen Treibhausgasminderungsquote, Hintergrundpapier. Leipzig: DBFZ. 02/2021

[27] https://www.bmu.de/fileadmin/bmu-import/files/english/pdf/application/pdf/klimapaket_aug2007_en.pdf

[28] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en#documents

[29] https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/

[30] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32018R0842

[31] https://www.bundesregierung.de/breg-en/issues/climate-action/klimaschutzprogramm-2030-1674080

[32] https://www.bmu.de/en/publication/climate-action-plan-2050/

[33] https://www.bundesregierung.de/resource/blob/975226/1679914/e01d6bd855f0 9bf05cf7498e06d0a3ff/2019-10-09-klima-massnahmen-data.pdf?download=1

The main public drivers regarding policy in the transport sector are the revised EU Renewable Energy Directive (RED II)[34] and the Fuel Quality Directive (FQD)[35], which are implemented by the Federal Emissions Control Act (BImSchG §37)[36] and the GHG quota. By 2020, the target GHG reduction is set for 6% through alternative and renewable fuels, including the crediting of up to 1.2% upstream emission reductions per UER 2018. 37 Fuel suppliers will be obliged to report GHG emissions for the fuels they have placed on the market.[38] Most recently, the federal government agreed on key points for the national implementation of the RED II. In addition to the gradual increase of the GHG quota to 22% in 2030, it includes the setting of the cap for biofuels from cultivated biomass at 4.4% from 2026.[39] The national implementation of REDII and thus the adjustment of the GHG quota by 2030, was completed in June 2021. The current trend shows that the GHG quota alone will not meet the actual GHG reduction requirements of -40% by 2030 in comparison to 1990. In fact, fulfilment of this quota requires a high share of renewables in the transport sector, which can only be achieved when almost all low-carbon fuel options, including electricity, are considered.

During the last few years, Germany's public debate has been focusing on electric mobility, battery-powered vehicles, Power-to-X (PtX), and hydrogen. With regard to transport in the agricultural/forestry sector, tax relief for biofuels has been extended by the European Commission until the end of 2021, making the use of biofuels in this sector more competitive (UEBLL[40], EEAG[41]). Currently, the UEBLL is undergoing a revision: In July 2021, the EC published a proposal of the new Climate, Energy and Environmental State aid guidelines (KUEBLL; CEEAG) which is now under negotiation with the European Parliament, and the Council.[42]

To decarbonize the transport sector, high priority has recently been given not only to e-mobility for short-distance traffic and passenger cars, but also to extending compressed natural gas (CNG) infrastructure along the most important middle- and long-distance road networks. The federal government strongly supports the use of liquefied natural gas (LNG) for heavy-duty transport and waterborne application. CNG/LNG is discussed as controversial in expert groups such as the federal government-convened National Platform Future of Mobility (NPM).[43] The application of hydrogen as transport fuel is one of the keys within the National Hydrogen Strategy that was published in June 2020.[44]

A description of renewable energy and climate policies and measures in Germany is available at the IEA's Policies and Measures Database: https://www.iea.org/policies?country=Germany

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[34] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001

[35] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32009L0030

[36] https://www.gesetze-im-internet.de/bimschg/BJNR007210974.html

[37] https://www.gesetze-im-internet.de/uerv/UERV.pdf

[38] https://www.dbfz.de/fileadmin//user_upload/Referenzen/Statements/Hintergrundpapier_Weiterentwicklung_THG-Quote.pdf

[39] https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Glaeserne_Gesetze/19._Lp/thg_quote/Entwurf/thg_quote_refe_bf.pdf

[40] https://eur-lex.europa.eu/legal- content/EN/TXT/HTML/?uri=CELEX:52014XC0628(01)&from=DE

[41] https://www.ufop.de/presse/aktuelle-pressemitteilungen/eu-kommission-verlaengert-genehmigung-fuer-biokraftstoffe-der-land-und-forstwirtschaft/

[42] https://ec.europa.eu/commission/presscorner/detail/en/ip_21_2784

[43] https://www.plattform-zukunft-mobilitaet.de/en/

[44] https://www.bmbf.de/files/bmwi_Nationale%20Wasserstoffstrategie_Eng_s01.pdf

Specific policies related to renewable electricity, renewable heat and transport biofuels will be highlighted in the chapters about the role of bioenergy in different sectors.

THE CONTRIBUTION OF BIOENERGY IN NATIONAL ENERGY SUPPLY

TOTAL ENERGY SUPPLY

The total energy supply (TES) of Germany in 2019 amounted to 12,323 petajoule (PJ) with an export surplus of electricity of 118 PJ (1% of total energy supply). The energy system is still dominated by fossil fuels, representing two thirds of total energy supply: 4,172 PJ (33.9%) oil products, 3,166 PJ (25.7%) natural gas and 2,255 PJ (18.3%) coal products. Energy from non-renewable waste accounts for 178 PJ (1.4%). The statistics also feature 819 PJ (6.6%) of nuclear energy used to produce electricity.

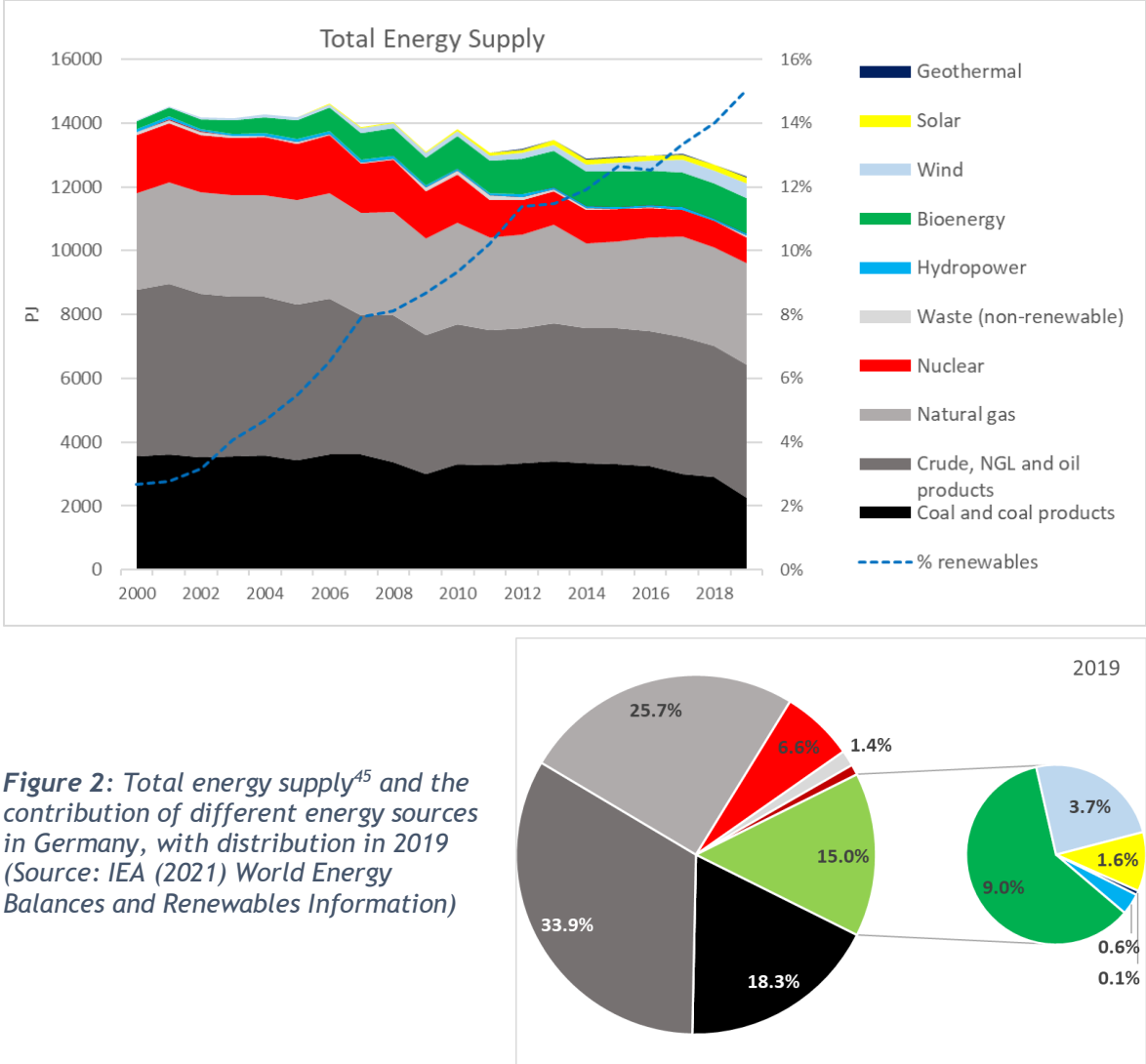

***Figure 2**: Total energy supply[45] and the contribution of different energy sources in Germany, with distribution in 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

[45] Total energy supply refers to the use of resources. In terms of the role in the energy system this distribution overestimates the role of resources producing electricity with a high share of unused waste heat (like nuclear plants).

Renewable energy sources have a share of 15% or 1,851 PJ. Around 60% of renewable energy supply in 2019 came from biomass (1115 PJ), followed by wind energy (453 PJ), solar energy (198 PJ), hydropower (71 PJ), and geothermal energy (14 PJ).[46]

In the past 10 to 15 years total energy supply steadily decreased at an average pace of 1% per year. The share of oil products was fairly stable around 33% of TES. Coal was stable around 25% of TES up to 2016, however, this dropped significantly – mostly in 2019 – to 18%. The share of gas was also quite stable between 21% and 23% of TES up to 2016. In the past years, its share increased to 26%, which seemed to partly compensate the drop in coal. The share of nuclear energy steadily declined from 11% in 2011 to 6.5% in recent years – this gradual phase-out was triggered by the nuclear incident in Fukushima, Japan in March 2011.

The share of renewable energy steadily increased from 3% of TES in 2000 up to 15% in 2019. Up to 2012 this growth was dominated by bioenergy; after 2012 the growth is mainly in wind and solar energy. Nevertheless, bioenergy still represents 60% of renewable energy supply in Germany.

The following figure shows the evolution of the different types of bioenergy; it shows the peak in bioenergy around 2012 and stabilisation afterwards. About half of the bioenergy consumed in Germany comes from solid biomass (541 PJ) of which 318 PJ is used in the residential sector. The role of biogas is substantial, with 316 PJ (28%). Other contributors are renewable municipal waste (129 PJ), biodiesel (86 PJ), bioethanol (30 PJ) and other liquid biofuels (6 PJ).

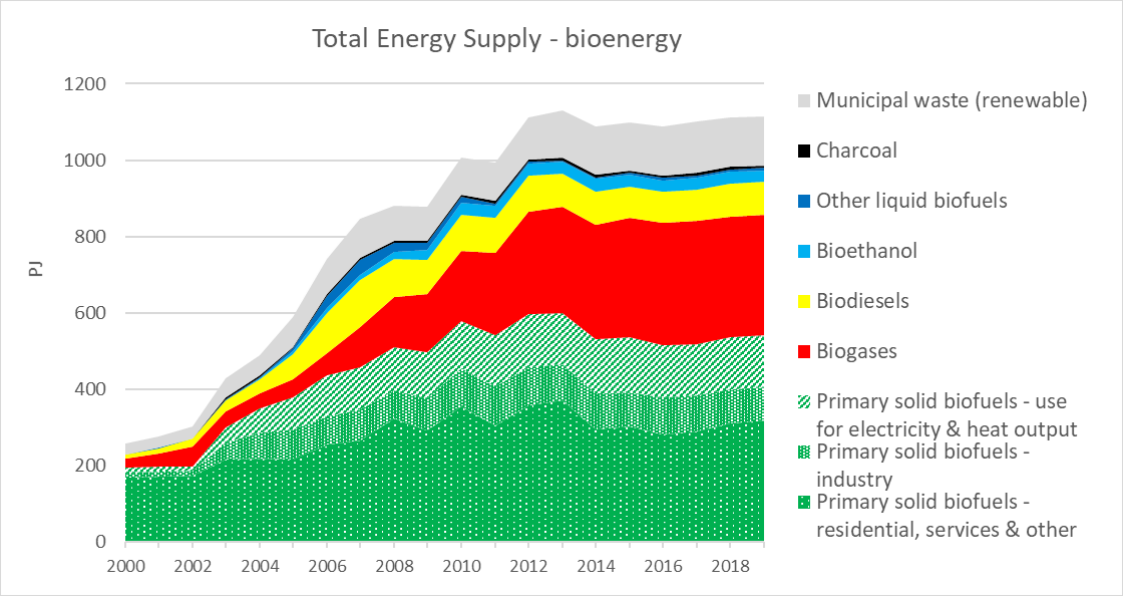

***Figure 3**: Development of total energy supply from bioenergy in Germany 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

[46] Data for 2020 is available on: https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

Evolution of the bioenergy carriers:

- Between 2002 and 2012 there was an important growth in solid biofuels from 200 PJ to 580 PJ, with growth in residential applications, industry use and use of solid biofuels of heat and power production. After that, there was a substantial reduction (~15%) in residential use, while the use in industry of for heat/power production was fairly stable.
- Biogas saw a strong growth from 25 PJ in 2000 to 315 PJ in 2015, making Germany a global leader in biogas. In the past years, the level of biogas has stabilized.
- Germany was one of the first European countries to adopt biodiesel, which was at around 10 PJ in 2000. After a substantial increase between 2004 and 2007 up to 160 PJ for biodiesel and pure plant oil combined, levels went down and have now stabilized around 90 PJ.
- Bioethanol was introduced in 2004 and increased up to 31 PJ in 2010. This level has stabilized since.
- Renewable municipal waste increased from 30 PJ in 2000 up to 130 PJ in 2014 and has stabilized around this level since.

Table 4 displays the 2019 total bioenergy supply values on a per capita basis. Compared to the other 24 member countries of IEA Bioenergy (expressed per capita), Germany ranks at the top for biogas, at the higher end for renewable MSW and in the middle for solid biofuels and liquid biofuels.

***Table 4**: Total energy supply per capita in 2019 for different bioenergy carriers*

	Supply per capita	*Median IEA Bioenergy members*
Bioenergy	13.4 GJ/cap	*10.6*
Solid biofuels	6.5 GJ/cap	*7.0*
Renewable MSW	1.5 GJ/cap	*0.8*
Biogas	3.8 GJ/cap	*0.7*
Liquid biofuels	1.5 GJ/cap	*1.5*

Source: IEA (2021) World Energy Balances and Renewables Information

Table 5 indicates the amounts of the different bioenergy carriers compared to some relevant reference points, namely the amount of forest in the country (for solid biomass), the amount of generated MSW (for renewable MSW used for energy), the amount of natural gas consumed in the country (for biogas) and the amount of fossil oil products consumed (for liquid biofuels).

Table 5: Comparison of the supply of different bioenergy carriers in 2019 to specific reference points

Compared to reference points				Median*
Bioenergy	9.0	%	of total energy supply	*7.2 %*
Solid biofuels	66.7	GJ/ha_forest	compared to the domestic hectares of forest land (excl. protected)	*21.3 GJ/ha_forest*
Renewable MSW	2.54	GJ/ton_MSW	compared to the total generated MSW in the country	*1.4 GJ/ton_MSW*
Biogas	0.100	GJ/GJ_NG	compared to natural gas supply	*0.023 GJ/GJ_NG*
Liquid biofuels	0.029	GJ/GJ_oil	compared to oil products supply	*0.028 GJ/GJ_oil*

Source: energy data from IEA (2021) World Energy Balances and Renewables Information; forest figures from FAOStat; waste figures from World Bank
** Median of the 25 member countries of IEA Bioenergy*[47]

Specific comments in relation to the reference points:

- The amount of solid biofuels compared to the domestic forest area is relatively high (~3.5 $tons_{\_dry\ mass}$ of wood per hectare[48]). That is partly related to the relatively high forest increment in Germany, partly also to imports of wood from neighbouring countries.
- The use of renewable MSW for energy production is comparable to other European countries with well-developed waste management systems.
- The production of biogas per capita is the highest in the world in Germany. While natural gas consumption in Germany is quite high (more than a quarter of total energy supply), the production of biogas is equivalent to around 10% of overall natural gas consumption.

[47] Comparative figures of the different IEA Bioenergy member countries are discussed in the central Countries' Report.
[48] Counted with a typical calorific value of wood (dry mass) of 19 $GJ/ton_{\_dry\ mass}$

ROLE OF BIOENERGY IN DIFFERENT SECTORS

OVERVIEW

The overall 2019 share of renewables in **final energy consumption** among electricity, transportation and heat sectors is a little over 18%. Mind that this figure is slightly higher than the share in total energy supply (where unused waste heat, e.g., in fossil or nuclear power production, is also included).

Table 6: Role of bioenergy and renewable energy in electricity, transport energy and fuel/heat consumption in 2019

Sector	Share of bioenergy	Share of renewable energy	Overall consumption
Electricity[49]	8.8%	42.6% (22% wind)	569 TWh (2048 PJ)
Transport energy (final consumption)	4.7%	5.4%	2378 PJ
Overall fuel and heat consumption[50]	Direct biomass: 11.6% Biobased heat: 1.9%	14.2%	4324 PJ
TOTAL FINAL ENERGY CONSUMPTION	10.0%	18.4%	8668 PJ

Source: IEA (2021) World Energy Balances and Renewables Information

In 2019, 10% of Germany's total final energy consumption in the heat, electricity and transport sectors (combined) was covered by biomass resources.[51] Germany has an important share of renewable electricity, distributed over the different renewable energy forms (wind, solar, biomass, hydro). More than half of the biomass contribution to renewable electricity comes from biogas. The share of biofuels for transport is around 5%. This figure was already reached in 2010 and has not increased since. Overall, the direct share of biomass for heating in the different sectors is a bit over 10%. Heat output generated and sold by CHP plants and heat plants represents around 10% of fuel/heat provided, of which on average 14% is produced from biomass. In the residential sector biomass represents about 13% of fuel/heat consumption.

The following paragraphs consider the evolutions in the different sectors.

[49] Renewable electricity production compared to final consumption. Potential renewable shares of imported electricity are not included.

[50] This includes final consumption of fuels and heat in industry, the residential sector, commercial and public services and agriculture/forestry. Transport fuels are excluded. Energy used for transformation and for own use of energy producing industries is also excluded.
Electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported.

[51] https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/erneuerbare-energien-in-zahlen-2019.html. Most recent statistics here: https://www.umweltbundesamt.de/publikationen/erneuerbare-energien-in-deutschland-2020 and https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

ELECTRICITY

The German power production used to be dominated by coal, nuclear energy, and some natural gas. Before 2005 **coal** represented more than 50% of power production in Germany (300 TWh); this slightly dropped to 280 TWh by 2015, still 45% of overall power production. In the past 5 years, and particularly in 2019, there was a serious drop in coal power to a level of 185 TWh, still a substantial level of 30% of overall power production. Up to 2006, **nuclear** energy produced around 170 TWh in Germany, representing almost 30% of power production. There was a step reduction in 2007 to 140 TWh. From 2011 levels have steadily decreased to 75 TWh in 2019, around 12% of German power production. This gradual phase-out was triggered by the nuclear incident in Fukushima, Japan in March 2011. The share of **natural gas** represented between 10 and 15% of power production in the past decades. In the past few years natural gas power has recovered from 63 TWh in 2015 to 95 TWh in 2019, thereby compensating for some of the reductions in coal power.

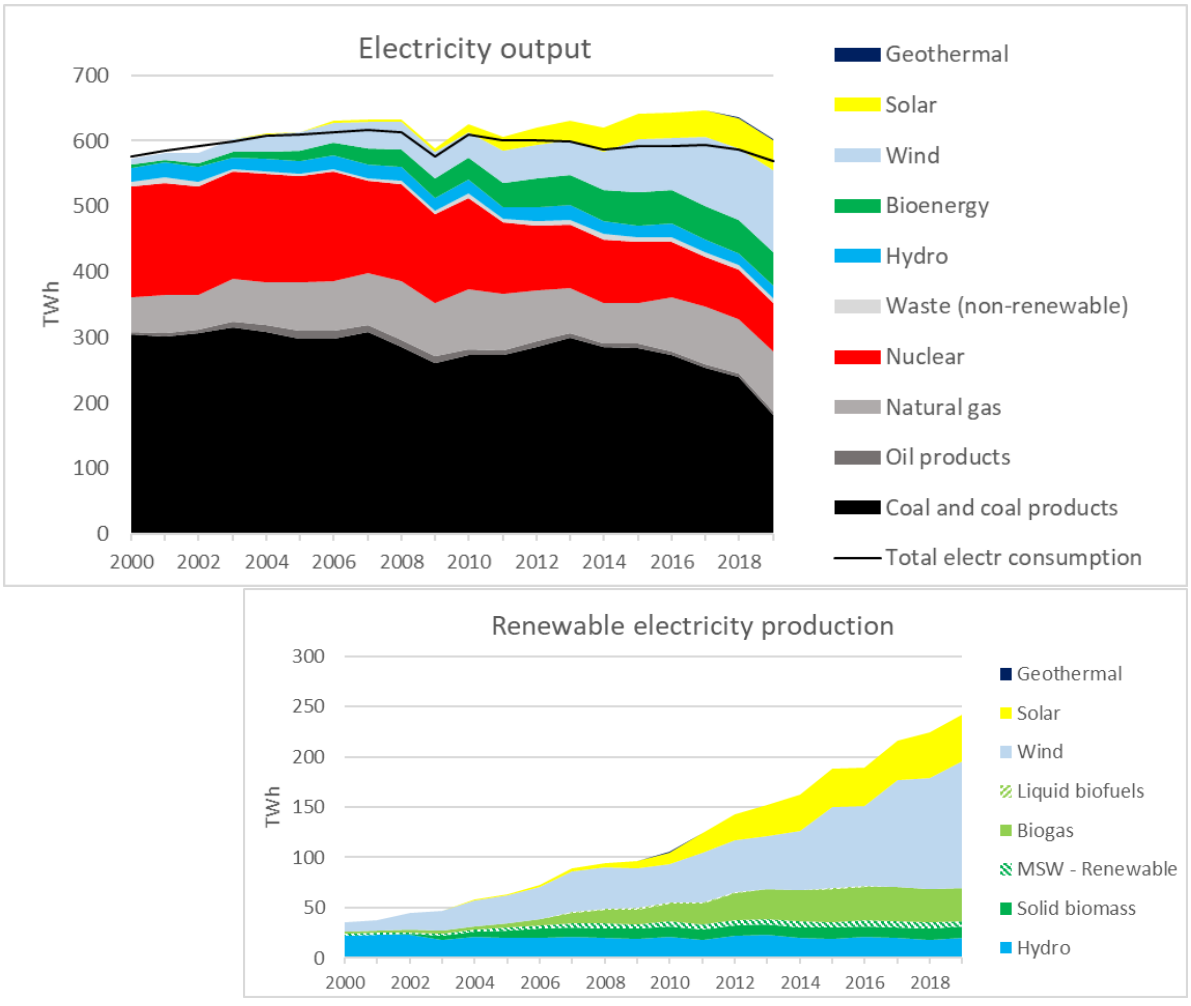

***Figure 4**: Evolution of the electricity mix in Germany 2000 - 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

The share of **renewable** electricity in electricity consumption increased steadily from 6% in 2000 to 42% in 2019. Wind power developed quite early and has consistently grown in the past decades up to 22% of electricity consumption (126 TWh). Biomass-based electricity increased from 5 TWh in 2000 to 50 TWh in 2014 and has stabilised since, currently representing 8.8% of electricity

consumption. Solar power increased steadily from 1 TWh in 2005 to 48 TWh in 2019, which is 8.2% of German electricity consumption. Hydropower is fairly constant around 20 TWh (3.5% of electricity consumption). Typically, 5 to 8% of electricity production was exported to neighbour countries.

Policy framework

The main relevant policy instruments (with relevance for biobased electricity) behind these evolutions are:

- Renewable Energy Sources Act (EEG) 2000 – operational subsidy (feed-in tariff system)[52]
- Renewable Energy Sources Act (EEG) 2017 – operational subsidy (auction/bidding system)[53]
- Renewable Energy Sources Act (EEG) 2021[54]
- Biomass electricity sustainability ordinance (BioSt-NachV) 2009[55]
- Biomass ordinance 2001[56]
- Climate Action Plan 2050[57]

HEAT/FUEL

Figure 5 shows the role of different fuels/energy carriers for providing heat in different sectors (industry, residential sector, commercial and public services and other). It also includes heat sold to customers, e.g., through district heating. Fuel use by energy producing industries for transformation and for own use is excluded. Mind that electric heating (direct or through heat pumps) is not included in these figures as this is not separately reported in the IEA database.

Fuel and heat consumption is still for 75% dominated by fossil fuels, mainly natural gas and oil. The share of oil is steadily decreasing, while natural gas has actually increased in the past 5 years, representing 50% of fuel/heat consumption. The direct use of biomass was relatively stable around 470 PJ, which is 11% of fuel/heat consumption. Solar thermal systems provide 0.7% of heat.

[52] https://www.bgbl.de/xaver/bgbl/start.xav#__bgbl__%2F%2F*%5B%40attr_id%3D%27bgbl100s0305.pdf%27%5D__1631852683643

[53] https://www.gesetze-im-internet.de/eeg_2014/EEG_2017.pdf

[54] https://www.gesetze-im-internet.de/eeg_2014/EEG_2021.pdf

[55] http://www.gesetze-im-internet.de/biost-nachv/BJNR217400009.html

[56] http://www.gesetze-im-internet.de/biomassev/BJNR123400001.html

[57] https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/

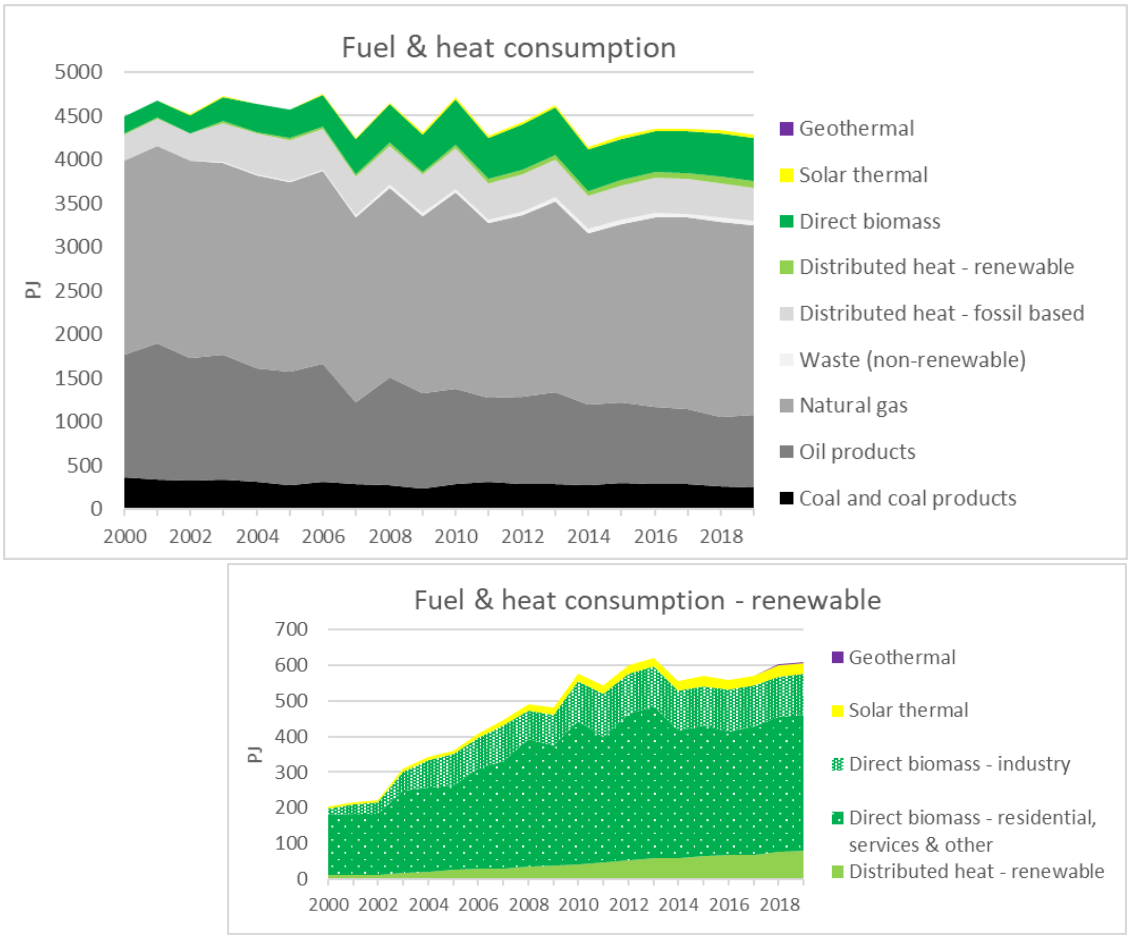

***Figure 5**: Evolution of fuel and heat consumption in Germany 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Heat output generated and sold by CHP plants and heat plants (e.g., through district heating) represents around 10% of fuel/heat provided. Figure 6 shows that this is still for more than 80% fossil based, with a dominant (and stable) role for natural gas; the role of coal is going down (but still substantial at around 25%), while biomass steadily increases, now reaching 17% of heat output.

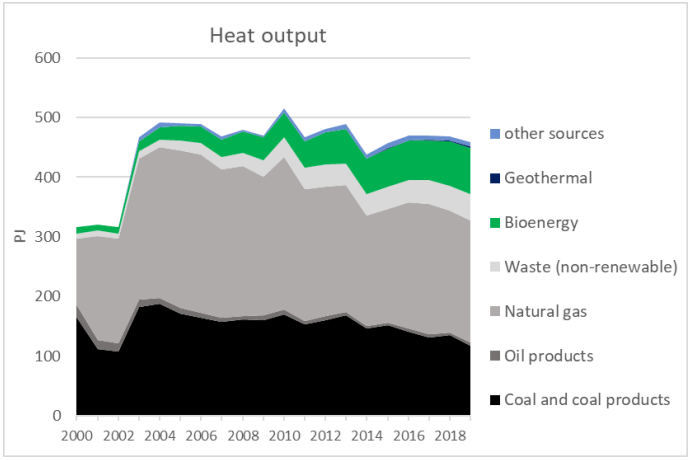

***Figure 6**: Evolution of fuels for heat output in Germany 2000 – 2018 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

The main relevant policy instruments behind these evolutions are:

- Market incentive programme (MAP) 1999 – financial subsidy
- Renewable Energies Heat Act (EEWärmeG) 2009 – building regulation[58]
- Energy Saving Ordinance (EnEV) based on the Energy Saving Act (EnEG)[59]
- Climate Action Plan 2050[60]
- Renewable Energy Sources Act (EEG) 2021[61]
- Integrated Energy and Climate Programme (IEKP) 2007/2008[62]
- Combined Heat and Power Ordinance (KWKG) 2002[63]

TRANSPORT

Figure 7 shows an overview of the energy used in transport in Germany, split up by different fuels/energy carriers.

Diesel is the dominant transport fuel in Germany; its role (fossil & biobased diesel) increased in the past decades up to 60% of transport fuel, while gasoline decreased to 30%. In the early 2000s, biodiesel already represented 1% of diesel consumption. This increased to more than 10% in 2006-2007 (145 PJ), partly through general blending, and partly through the use of pure biodiesel and pure plant oil. This brought Germany at the forefront of transport biofuels introduction in Europe. In the following years the use of pure biofuels was reduced and focus shifted to general blending. Levels of biodiesel have stabilized between 80 and 90 PJ (5-6% of diesel fuels, by energy) and the role of pure plant oil dropped from 30 PJ to nearly zero. Additionally, the resource base shifted towards residues and waste, which is currently the basis for about 35% of the German biodiesel.[64]

Bioethanol blending in gasoline was introduced in 2004 and gradually increased to 33 PJ in 2012, representing an average share of 4% in gasoline (by energy). This level has also stabilized since 2012.

There is also some natural gas use in the German vehicle fleet, around 1% of transport fuels. Of that amount, around 7% is biogas.

Electricity represents a share of 1.8% of total transport energy use. This is mostly in rail - the use of electricity in road vehicles is still marginal in 2019 (0.05% of total transport energy use) but can be expected to grow in the coming years.

[58] https://www.dena.de/en/topics-projects/energy-efficiency/buildings/consulting-and-planning/german-energy-saving-ordinance-enev-standards-and-laws/
[59] BMWi - Energieeinsparverordnung
[60] https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/
[61] https://www.gesetze-im-internet.de/eeg_2014/EEG_2021.pdf
[62] https://www.bmwi.de/Redaktion/DE/Textsammlungen/Industrie/integriertes-energie-und-klimaprogramm.html
[63] https://www.bmwi.de/Redaktion/DE/Gesetze/Energie/KWKG-2016.htm
[64] https://www.dbfz.de/pressemediathek/publikationsreihen-des-dbfz/dbfz-reports/dbfz-report-nr-11/#c3066

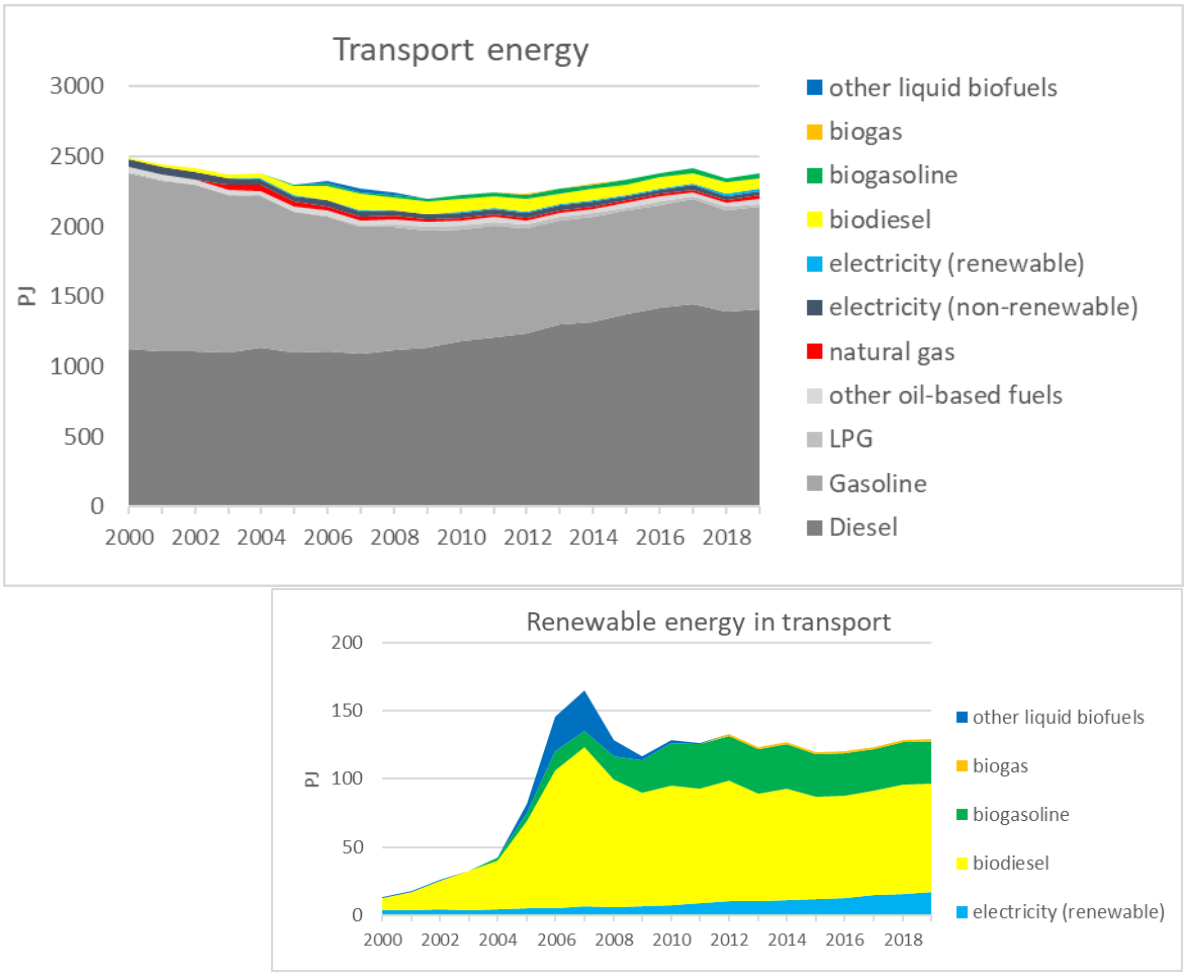

***Figure 7**: Evolution of transport fuels in Germany 2000 – 2019 (Source: IEA (2021) World Energy Balances and Renewables Information)*

Policy framework

The main relevant policy instruments behind these evolutions are:

- National implementation of RED II[65]
- National Hydrogen Strategy 2020[66]
- Act to introduce a biofuel quota by amending the Federal Immission Control Act (BImSchG) and Biofuel Quota Act 2006 - regulation[67]
- Definition of a biofuel quota (target of 8% energetic until 2015)
- From 2015 this quota was replaced by a GHG-mitigation quota (target of 6% until 2020)
- Energy Tax Act (EnergieStG) 2009[68] – tax incentives
- Tax exemption and relief for biofuels

[65] https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii
[66] https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.html
[67] https://www.bmwi.de/Redaktion/EN/Artikel/Energy/petroleum-biofuels-and-alternative-fuels.html and https://www.bmu.de/en/pressrelease/minister-schulze-we-are-promoting-fuels-that-mitigate-climate-change-without-destroying-nature/
[68] EnergieStG - nichtamtliches Inhaltsverzeichnis (gesetze-im-internet.de)

- Biofuel sustainability ordinance (Biokraft-NachV) 2009
- Definition of requirements for the use of biomass for biofuels

COMPARISON WITH RENEWABLE ENERGY TARGETS

According to Eurostat, the following renewable energy shares in *gross final energy consumption* were reached.

***Table 7**: Share of renewables in different sectors in Germany, according to Eurostat[69] (2005-2019) and Federal Environment Agency (UBA)[70](2020),*

	2005	2010	2015	2019	2020*	*2020 target*
Overall share	6.7%	10.5%	14.6%	17.4%	19.3%	*18%*
In heating & cooling	6.8%	9.8%	12.9%	14.6%	15.2%	*15.5%*
In electricity	10.5%	17.3%	30.8%	40.8%	45.4%	*38.6%*
In transport	4.0%	6.4%	6.6%	7.7%	7.3%	*10%*

** Gross final energy consumption impacted by the COVID pandemic*

In 2020, Germany reached its overall renewable energy target, and went even beyond, particularly for renewable electricity. Renewable energy in German transport has not seen major increases in the past decade – there has been a shift to biodiesel from used cooking oil, which could be double counted towards the European target for renewable energy in transport. Nevertheless, the 10% target for 2020 has not been reached.

Mind that some of these figures can differ from the IEA derived data because of different accounting rules. Particularly in transport the Eurostat shares are higher, which is due to the multiple counting of advanced biofuels and renewable electricity towards the transport target. The heating & cooling figure in Eurostat also includes heat pumps.

RESEARCH FOCUS RELATED TO BIOENERGY

Germany has implemented an active policy for the transition of the energy system towards greater use of renewable energy sources more than a decade ago, which has led to a strong increase in the amount of biomass used for electricity, heat and the provision of transport fuel.[71] At the same time

[69] https://ec.europa.eu/eurostat/web/energy/data/shares

[70] https://www.umweltbundesamt.de/en/topics/climate-energy/renewable-energies/renewable-energies-in-figures

[71] Thrän, D. (2015): Introduction. In D. Thrän (ed.): Smart bioenergy: technologies and concepts for a more flexible bioenergy provision in future energy systems (p. 1). Cham: Springer. https://www.springer.com/de/book/9783319161921

bioenergy research is fostered by several research programmes on the national level provisioned e.g. by the German Federal Ministry of Research and Education (BMBF)[72], the Ministry for Economy Affairs and Energy (BMWi)[73], and the Ministry of Food and Agriculture (BMEL) which has the lead for bioenergy research on the federal level[74]. The funding areas in the area of bioenergy in Germany are biomass from agriculture, forestry and aquatic sources, the utilisation of biogenic waste from agriculture and forestry, aquaculture, the processing industry, commerce and households, and the generation, handling, processing and use of renewable resources, as well as cross-cutting issues in the area of bioenergy such as a dialogue with society. BMBF, BMWi and BMEL coordinate their R&D funding activities in the 7th Energy Research Programme[75]. In addition, the Ministry of Environment (BMU) and the Ministry of Transport (BMVI) pursue activities relevant for bioenergy research, the BMVI with a large programme on renewable fuels for transport.[76]

Germany has a rather complex bioenergy research landscape with a multitude of activities on federal and state level, and smaller and larger industries in many different application areas. Some examples of main actors:

- The Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe e.V., FNR) is the coordinating agency for bioenergy and bioproducts in Germany; a key task is the administration of the R&D budget of the BMEL amounting to ca. EUR 150 million in 2021 provided via two funding programmes (renewable resources programme on bioenergy and bioproducts | FPNR; no fixed budget share for one or the other; energy and climate funds (EKF) including forest and climate funds | WKF). FNR represents Germany in IEA Bioenergy. See www.international.fnr.de

- The German Biomass Research Centre (Deutsches Biomasseforschungszentrum – DBFZ) was founded in 2008 by the BMEL and was commissioned to theoretically and practically promote the efficient use of biomass as a renewable energy source of the future within the scope of applied sciences.[77] http://www.dbfz.de/en/the-dbfz.html

- The Federal Thuenen Institute covers other aspects of bioenergy, e.g., plant production, renewable resources forest management, GHG emissions, etc. See http://www.thuenen.de/en/

- The Karlsruhe Institute of Technology (KIT) is one of Europe's leading energy research establishments with huge expertise, e.g., on thermochemical conversion routes. See www.kit.edu

- The Technology and Support Centre (TFZ) is an institution of the Bavarian Ministry of Food, Agriculture and Forestry (Bayerisches Staatsministerium für Ernährung, Landwirtschaft und Forsten). The main goals of the TFZ are the support of the agricultural production, the processing and utilization of renewable resources by applied research, the development and testing of products and methods, and the transfer of technology by demonstration and education. See http://www.tfz.bayern.de/en/index.php

[72] https://www.bmbf.de/en/sustainable-development-2312.html
[73] https://www.energetische-biomassenutzung.de/en/start
[74] http://international.fnr.de/renewable-resources/bioenergy/
[75] 2021 Federal Government Report on Energy Research: https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/federal-government-report-on-energy-research-2021.html
[76] https://www.bmvi.de/SharedDocs/DE/Artikel/G/neues-foerderkonzept-erneuerbare-kraftstoffe.html
[77] https://www.dbfz.de/en/research.html

RECENT MAJOR BIOENERGY DEVELOPMENTS

Overall bioenergy stagnated in recent years, due to other RES gaining importance and fundamental discussions about sustainability of biomass and biofuels. There is also an ongoing discussion about the role of bioenergy in a flexible energy system with huge contributions of fluctuating RES, and bioenergy/biomass in a circular economy (biorefinery approach).

In the heating sector, the energy supply from renewable energy sources from 1990 to 2018 increased more than five times from just over 32 TWh to about 171 TWh, thereof 147 TWh from biomass. Thus, this share significantly increased from approximately 68% in 2009 to 87% in 2018.

Electricity production from bioenergy has increased during past years as well: While in the year 2000 just 0.21 TWh electricity was produced from biomass[78], bioenergy power plants produced 38.36 TWh electricity under the Renewable Energy Sources Act. In 2018, the produced electricity remained approximately at the same level with 51.3 TWh, when compared to 2016.[79] Flexible power provision from biomass is today possible in many biogas plants, however there is still lack of incentives, to full use the flexible generation.

Transport sector: The development of production and the use of conventional biofuels such as biodiesel (FAME), bioethanol, HVO/HEFA and biomethane are a story of ups and downs, highly affected by policy frame and market developments (e.g., prices for feedstock and revenues for by-products as well as increasing role of actual GHG emission savings per fuel portfolio). In Germany, 55.9 million t fuels were used in the transport sector in 2018. Besides diesel with 63.3 % and gasoline with 30.6 % the share of biofuels amounted to 5% or rather 3.5 million t.[56] Biomethane is produced in significant capacities but for different markets. In Germany, a network of more than 900 natural gas filling stations is available for currently more than 98,000 natural gas vehicles. Thereof 150 filling stations offer 100 % CNG from biomethane (as Bio-CNG) and more than 300 filling stations offer mixtures of biomethane and natural gas. The sales of biomethane as fuel was 379 GWh in 2016, and reached 401 GWh in 2018.[56]

The main government focus is on electrification. There is a fundamental discussion about the role of combustion engines in the future. In addition, there is competition between biofuels and renewable fuels (PtL etc.). Both government and stakeholders have high expectations in green hydrogen. Additionally, carbon dioxide removal (CDR) became an increasing issue in the debates. It is now a research topic.

[78] https://www.bmwi.de/Redaktion/DE/Artikel/Energie/energiedaten-gesamtausgabe.html

[79] https://www.fnr.de/fileadmin/allgemein/pdf/broschueren/broschuere_basisdaten_bioenergie_2020_engl_web.pdf

LINKS TO SOURCES OF INFORMATION

IEA Energy Policy Review – Germany 2020: https://www.iea.org/reports/germany-2020

Renewable energy statistics: https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/erneuerbare_energien_in_zahlen.html

Working group on renewable energy statistics: https://www.umweltbundesamt.de/tags/agee-stat

Bioenergy portal of FNR with brochures for download, statistics, etc: http://bioenergie.fnr.de/

Website of DBFZ with bioenergy reports etc.: www.dbfz.de/en/

BMWi overview of all energy related legislation in Germany: https://www.bmwi.de/Redaktion/DE/Publikationen/Energie/gesetzeskarte.html

German Energy Agency: https://www.dena.de/en/home/