IEA Bioenergy
Technology Collaboration Programme

Implementation of bioenergy in Germany - 2024 update

Country Reports

IEA Bioenergy: 12 2024

This report was prepared based on data from the 2024 IEA World Energy Balances and Renewables Information[1], combined with data and information provided by the IEA Bioenergy Executive Committee and Task members. 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 17% of *total energy supply* in Germany in 2022. The renewable energy share in *final energy consumption* is 21%[2]. Around 55% of renewable energy is from biomass.
- Fossil fuels still represent 80% of total energy supply in Germany. In terms of oil and gas consumption, Germany is almost completely reliant on imports; the import dependency of coal is 50% currently. In contrast, for biofuels and waste import dependency is around zero so it makes an important contribution to energy security.
- 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 in Germany was dominated by bioenergy; after 2012, the growth has mainly been in wind and solar energy. But these are predominantly aimed at electricity production, which represents a quarter of final energy consumption. Important steps still need to be taken in renewable heat production and renewable energy in transport.
- About half of the bioenergy consumed in Germany comes from solid biomass; most is residential heating, but there is also substantial use in industry and for heat and power production. Levels

[1] www.iea.org/statistics

[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).

of biomass use in these sectors have been fairly stable in the past decade.

- The role of biogas is substantial (top in the world, expressed per capita), equivalent to 10% of natural gas consumption, which is impressive considering the important role of natural gas in the German energy system. Nevertheless, further growth of biogas has been limited since 2014. In recent years there is renewed growth, particularly for grid injection of biomethane.

- Germany used to be the world leader in biodiesel and pure plant oil, peaking at 10% of diesel consumption in 2007, with a considerable part being applied as pure biofuel. After 2007, the shift has focused to general blending and the use of pure biofuels dropped to zero. In the past decade, levels of transport biofuels have stabilized around 5-6%. There has been some shift to waste-based biofuels which can be double counted for the European targets for transport.

- The national Climate Protection Act, approved in June 2021 and adapted in July 2024[3], reflects increasing GHG reduction targets of Germany towards climate neutrality by 2045. The current absolute GHG emissions reduction amounts to 46% (compared to 1990 levels)[4]. This amendment provides new impetus to renewable energy sources. The hydrogen economy is one of Germany's key ambitions[5].

[3] https://www.bundesregierung.de/breg-de/themen/tipps-fuer-verbraucher/klimaschutzgesetz-2197410

[4] https://www.umweltbundesamt.de/daten/klima/treibhausgas-emissionen-in-deutschland#emissionsentwicklung

[5] https://www.bmwk.de/Navigation/DE/Wasserstoff/wasserstoffstrategie.html

CONTENT

HIGHLIGHTS 1
CONTENT 3
COUNTRY PROFILE 4
Population and land use 4
Final energy consumption 4
THE CONTRIBUTION OF BIOENERGY IN NATIONAL ENERGY SUPPLY 5
Total energy supply 5
Evolution of bioenergy in total energy supply 6
Energy Dependency 8
NATIONAL POLICY FRAMEWORK IN GERMANY 9
Targets and strategies 9
ROLE OF BIOENERGY IN DIFFERENT SECTORS 11
Overview 11
Electricity 12
Heat/Fuel consumption 16
Transport 18
Gas consumption and the role of biogas/biomethane 21
Final energy consumption in different sectors (excl transport) 22
Final Energy consumption in industries 22
Final Energy consumption in the residential sector 23
Final Energy consumption in commercial and public services 24
Comparison with renewable energy targets 25
RESEARCH FOCUS RELATED TO BIOENERGY 26
RECENT MAJOR BIOENERGY DEVELOPMENTS 27
LINKS TO SOURCES OF INFORMATION 28

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 83.8 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 (48%) is agricultural land, of which about two-thirds are arable land and one-third permanent meadows/pastures. Wheat, barley, corn (maize), and sugar beets are the principal crops. 11.4 million hectares, or 32% of German land is forest land, of which half is planted forest. 48% of the German forest area is private forest, 29% state forest of the federal states, 19% corporate forest and 3.5% federal state forest. Small- and medium-sized forest-based enterprises play a major role in rural employment structures.

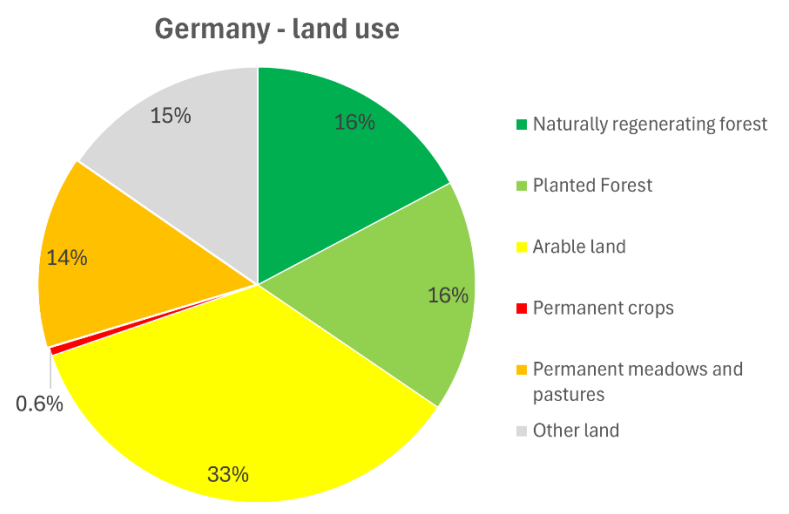

***Figure 1**: Land use in Germany (2022 figures - Source: FAOstat)*

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 2.5 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.

***Table 1**: Distribution of the final consumption of energy carriers by sector in Germany (2022 figures - Source: IEA (2024) World Energy Balances and Renewables Information)*

Final consumption energy carriers	Toe/capita (2022)	% of total	*Median* (toe/capita)*
Industry (energy use)	0.64	26%	*0.70*
Industry (non-energy use)	0.24	10%	*0.25*
Transport	0.61	24%	*0.72*
Residential	0.67	27%	*0.51*
Commercial & public services	0.30	12%	*0.31*
Other	0.05	2%	*0.10*
Total	2.50		*2.50*

** Median of the 23 member countries of IEA Bioenergy*[6]

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

THE CONTRIBUTION OF BIOENERGY IN NATIONAL ENERGY SUPPLY

TOTAL ENERGY SUPPLY

The total energy supply (TES) of Germany in 2022 amounted to 11.36 exajoule (EJ) with an export surplus of electricity of 0.10 EJ. The energy system is still dominated by fossil fuels, representing 80% of total energy supply: 3.79 EJ (33.4%) oil products, 2.79 EJ (24.6%) natural gas and 2.32 EJ (20.5%) coal products. Energy from non-renewable waste accounts for 0.17 EJ (1.5%). The statistics also feature 0.38 PJ (3.3%) of nuclear energy used to produce electricity.

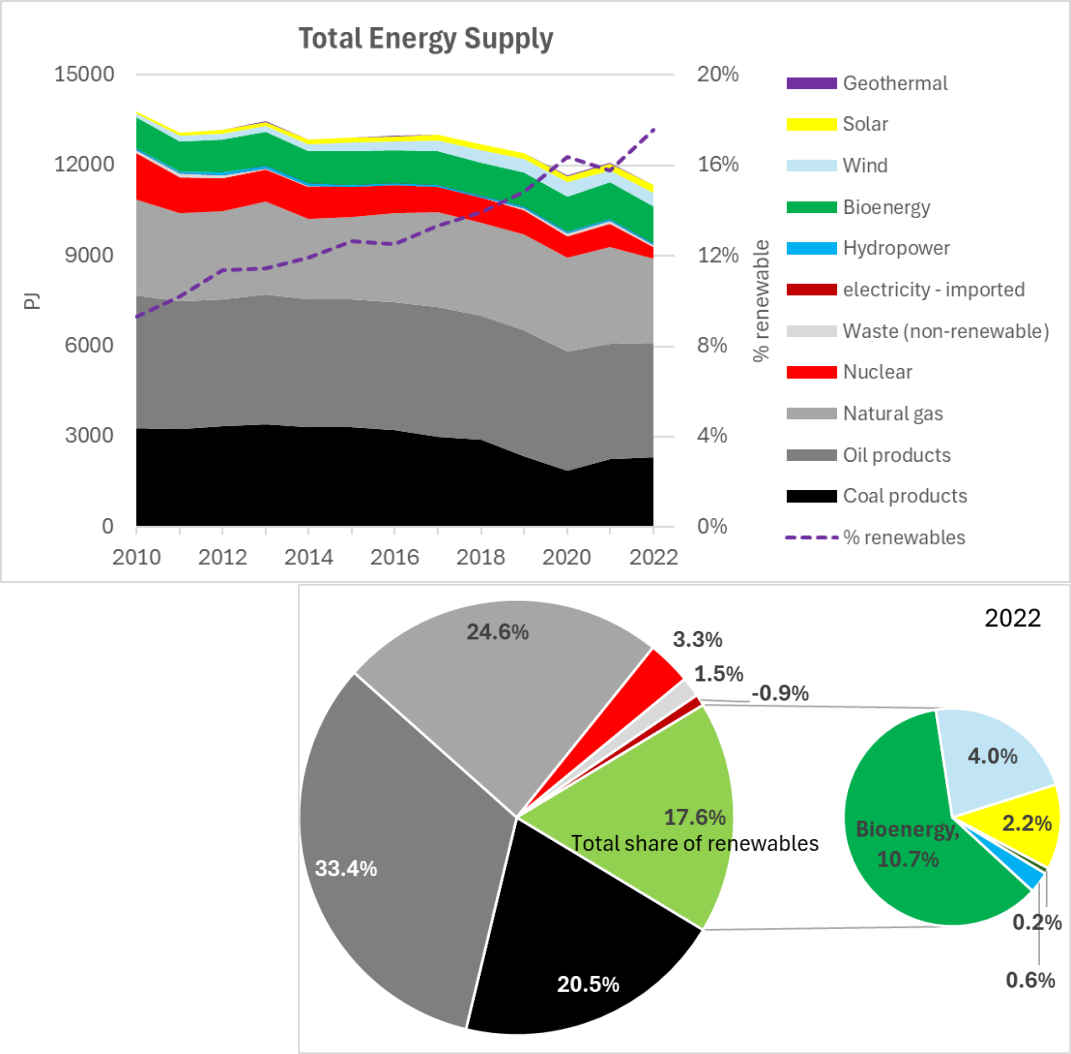

***Figure 2**: Total energy supply[7] and the contribution of different energy sources in Germany, with distribution in 2022 (data source: IEA (2024) World Energy Balances and Renewables Information)*

[7] Total energy supply represents all the energy required to supply end users in the country. Some of these energy sources are used directly while most are transformed into fuels or electricity for final consumption. 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 coal and nuclear plants).

Renewable energy sources have a share of 17.6% or 1.99 EJ. Around 60% of renewable energy supply in 2022 came from biomass (1.21 EJ), followed by wind energy (0.45 EJ), solar energy (0.25 EJ), hydropower (0.06 EJ), and geothermal energy (0.02 EJ).

In the past 10 years total energy supply steadily decreased at an average pace of around 1% per year. The share of oil products was fairly stable around 32-34% of TES. Coal was stable around 25% of TES up to 2016; after that it dropped to 16% in 2020; meanwhile, in the past few years the share of coal in TES increased again to 20%. The relatively high reliance on coal goes against the trend in other European countries. The share of gas was also quite stable between 21% and 23% of TES up to 2016; after 2016 its share increased to 27%, partly compensating for the decrease in coal. In 2022 there was a 13% drop in gas consumption compared to 2021, which can be linked to the Russian invasion in Ukraine, leading to price spikes of natural gas and measures to reduce Europe's reliance on Russian gas. Nuclear energy represented 11-13% of TES up to 2010; after that its share decreased to 8% in 2013 and further to 6% in 2020-2021. In 2022 the production of nuclear energy halved (down to a level of 3.3% of TES), due to the closing of nuclear plants. The last electricity from nuclear energy went into the grid on 15 April 2023.

The share of renewable energy steadily increased from 9% of TES in 2000 up to 17.6% in 2022. Up to 2012, this growth was dominated by bioenergy; after 2012, the growth was mainly in wind (offshore and on shore) and solar energy. Nevertheless, bioenergy still represents 60% of renewable energy supply in Germany.

EVOLUTION OF BIOENERGY IN TOTAL ENERGY SUPPLY

Figure 3 shows the evolution of the different types of bioenergy; it shows the peak in bioenergy around 2012, stabilisation up to 2019, and some increase again in the past few years.

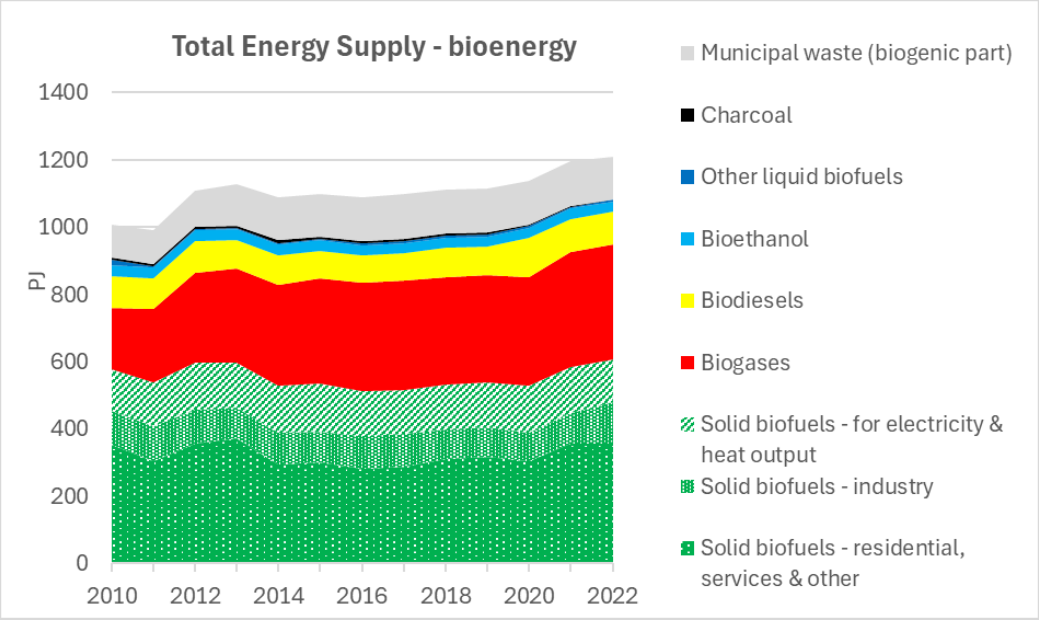

Figure 3: Development of total energy supply from bioenergy in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

About half of the bioenergy consumed in Germany comes from solid biomass (608 PJ) of which 357 PJ is used in the residential sector. The role of biogas is substantial, with 340 PJ (28%). Other contributors are renewable municipal waste (127 PJ), biodiesel (98 PJ), bioethanol (32 PJ) and other liquid biofuels (4 PJ).

Evolution of the bioenergy carriers:

- Between 2002 and 2012 there was an important growth in solid biofuels from 200 PJ to 600 PJ, with growth in residential applications, industry use and use of solid biofuels of heat and power production, see 2021 Country Report[8]. After that, the use of solid biomass stabilized, with some moderate increase again in residential applications in recent years.
- Biogas saw a strong growth from 25 PJ in 2000 to 315 PJ in 2015, making Germany a global leader in biogas, see 2021 Country Report. After 2015 the level of biogas stabilized around 320 PJ; there was a slight increase up to 340 PJ in recent years. Biogas and biomethane will be further discussed in a dedicated chapter.
- 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, see 2021 Country Report. In recent years there is a moderate increase of biodiesels again. Bioethanol was introduced in 2004 and increased up to 31 PJ in 2010, see 2021 Country Report. This level has stabilized since. Liquid biofuels will be further discussed in the chapter on transport.
- Renewable municipal waste increased from 30 PJ in 2000 up to 130 PJ in 2014 and has stabilized around this level since.

[8] https://www.ieabioenergy.com/wp-content/uploads/2021/11/CountryReport2021_Germany_final.pdf

ENERGY DEPENDENCY

The following graphs show the difference between domestic production and total energy supply of different energy carriers. Based on the difference between these figures, we can deduct the energy import dependency.

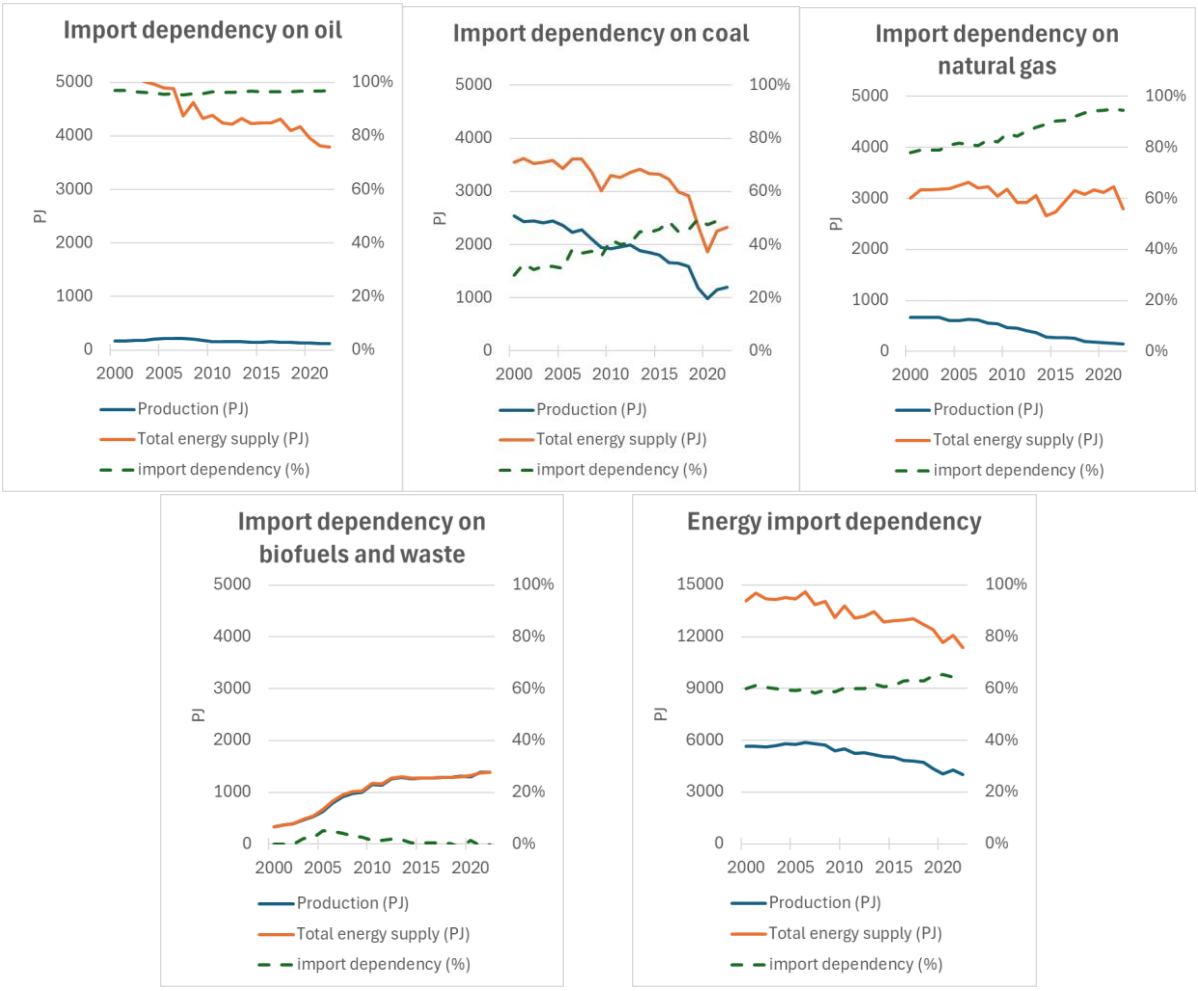

***Figure 4**: Evolution of energy import dependency for different energy carriers in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)*

In terms of oil and gas consumption, Germany is 90 to 100% reliant on imports. For coal products, there used to be substantial domestic production, but this has gone down over the years; the import dependency of coal is currently around 50%. In contrast, for bioenergy carriers and waste import dependency is around zero so it makes an important contribution to energy security.

With most bioenergy and other types of renewable energy (hydro, wind, solar) being produced domestically, this leads to an overall energy import dependency of 60%.

When looking at the different bioenergy carriers, in 2022 there were 7 PJ net imports of solid biofuels (1% of domestic consumption), 16 PJ imports of bioethanol (50% of domestic consumption), most of these coming from neighbour countries. On the other hand, there were net exports of 30 PJ biodiesel from Germany to neighbour countries. Biofuel imports and exports fluctuate significantly between years. All biogas and energy from waste was produced from domestic sources.

NATIONAL POLICY FRAMEWORK IN GERMANY

TARGETS AND STRATEGIES

According to its updated National Energy and Climate Plan[9] (August 2024) , Germany has a national target of 42.5% renewable energy in the gross final energy consumption by 2030. This is in line with the recommendations from the EC from Dec 2023. Moreover, Germany plans a more ambitious delivery of its national contribution to renewables than the required reference levels. 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% (previously 55%) by 2030 and a new reduction target of 88% for 2040. Under the latest legislation, sectoral targets are not binding anymore but for orientation only. For electricity, the aim is 600 TWh by 2030 or 80% of total electricity production. Measures are summarised in the 2023 Climate Action Programme of the German Federal Government.[10]

Table 2: *Renewable energy (RE) and climate targets in Germany.*[11,1213]

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
Heating and cooling	17.7 % (2023)	
Electricity	52,5 % (2023)	
Transport	7.5 % (2023)	

The corresponding national German Climate Action Plan (passed in 2016 and amended in 2021) 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

[9] https://commission.europa.eu/publications/germany-final-updated-necp-2021-2030-submitted-2024_en

[10] https://www.bmwk.de/Redaktion/EN/Downloads/C/climate-action-programme-2023.pdf?__blob=publicationFile&v=2

[11] Climate Action Plan: https://www.bmuv.de/publikation/climate-action-plan-2050-de

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

[13] https://www.gesetze-im-internet.de/englisch_ksg/englisch_ksg.pdf

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.

***Table 3**: German Climate Action Plan (2021): 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[14] established an EU-wide binding renewable energy target of 32% by 2030. With the European Green Deal Communication[15] 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. The 'fit for 55' package was presented by the European Commission in July 2021. By October 2023, all legal measures supporting this package were implemented.[16]

In addition, Germany is currently elaborating a Carbon Management Strategy[17] and a Long-Term Negative Emission Strategy[18]. Under this umbrella, national targets for technical carbon dioxide removal options, such as BECCS, are expected, as well as implementation strategies.

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

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.

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

[15] https://eur-lex.europa.eu/resource.html?uri=cellar:b828d165-1c22-11ea-8c1f-01aa75ed71a1.0002.02/DOC_1&format=PDF

[16] https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/delivering-european-green-deal_en#documents

[17] https://www.bmwk.de/Redaktion/EN/Downloads/E/240226-eckpunkte-cms-en.pdf?__blob=publicationFile&v=2

[18] https://www.bmwk.de/Redaktion/DE/Downloads/E/240226-eckpunkte-negativemissionen.pdf?__blob=publicationFile&v=4

ROLE OF BIOENERGY IN DIFFERENT SECTORS

OVERVIEW

The overall 2022 share of renewables in **final energy consumption**[19] among electricity, transportation and heat sectors is around 21%. Mind that this figure is slightly higher than the share in total energy supply (where unused waste heat, e.g., in coal or nuclear power production, is also included).

In 2022, 11% of Germany's total final energy consumption in the heat, electricity and transport sectors (combined) was covered by biomass resources.

__Table 4__: Role of bioenergy and renewable energy in electricity, transport energy and fuel/heat consumption as well as final energy consumption in 2022

Sector	Share of bioenergy	Share of renewable energy	Overall consumption
Electricity[20]	8.8%	46.0% *(23% wind; 11% solar)*	546 TWh (1964 PPJ)
Transport energy (final consumption)	5.8%	6.8%	2127 PJ
Overall fuel and heat consumption[21]	Direct biomass: 13.5% Biobased heat: 1.8%	16.3%	4184 PJ
TOTAL FINAL ENERGY CONSUMPTION	**11.4%**	**20.8%**	**8228 PJ**

Based on own calculations. Source of the data: IEA (2024) World Energy Balances and Renewables Information

Electricity represents around 24% of final energy consumption, transport fuels (excl. electricity) represent another 25% and other fuels/heat (excl. electricity) 51%.

The following paragraphs consider the evolutions in the different sectors.

[19] Final energy consumption excludes non-energy use of coal, oil products and natural gas

[20] Renewable electricity production compared to final consumption.

[21] 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.

ELECTRICITY

The German power production used to be dominated by coal, nuclear energy, and some natural gas. Up to 2015, **coal** represented more than 45% of power production in Germany (280-300 TWh). Since 2016, there has been a steady decline of coal power, down to 150 TWh in 2020, representing 25% of power production, which is still substantial. However, in 2021-2022, there was a slight recovery of coal power up to 190 TWh, connected to the phase out of nuclear energy. Preliminary data suggest that coal power in 2023 went down again to 2020 levels.

Up to 2006, **nuclear** energy produced around 170 TWh in Germany, representing almost 30% of power production, see 2021 Country Report. The level of nuclear power went down gradually after 2006, also triggered by the nuclear incident in Fukushima, Japan in March 2011. Nuclear power stabilized around 70-80 TWh between 2017 and 2021. In 2022 there was a step change to 35 TWh, related to the closure of nuclear plants. In 2023 only 7 TWh was produced in nuclear plants, which is slightly more than 1% of German power production. The last electricity from nuclear energy went into the grid on 15 April 2023.

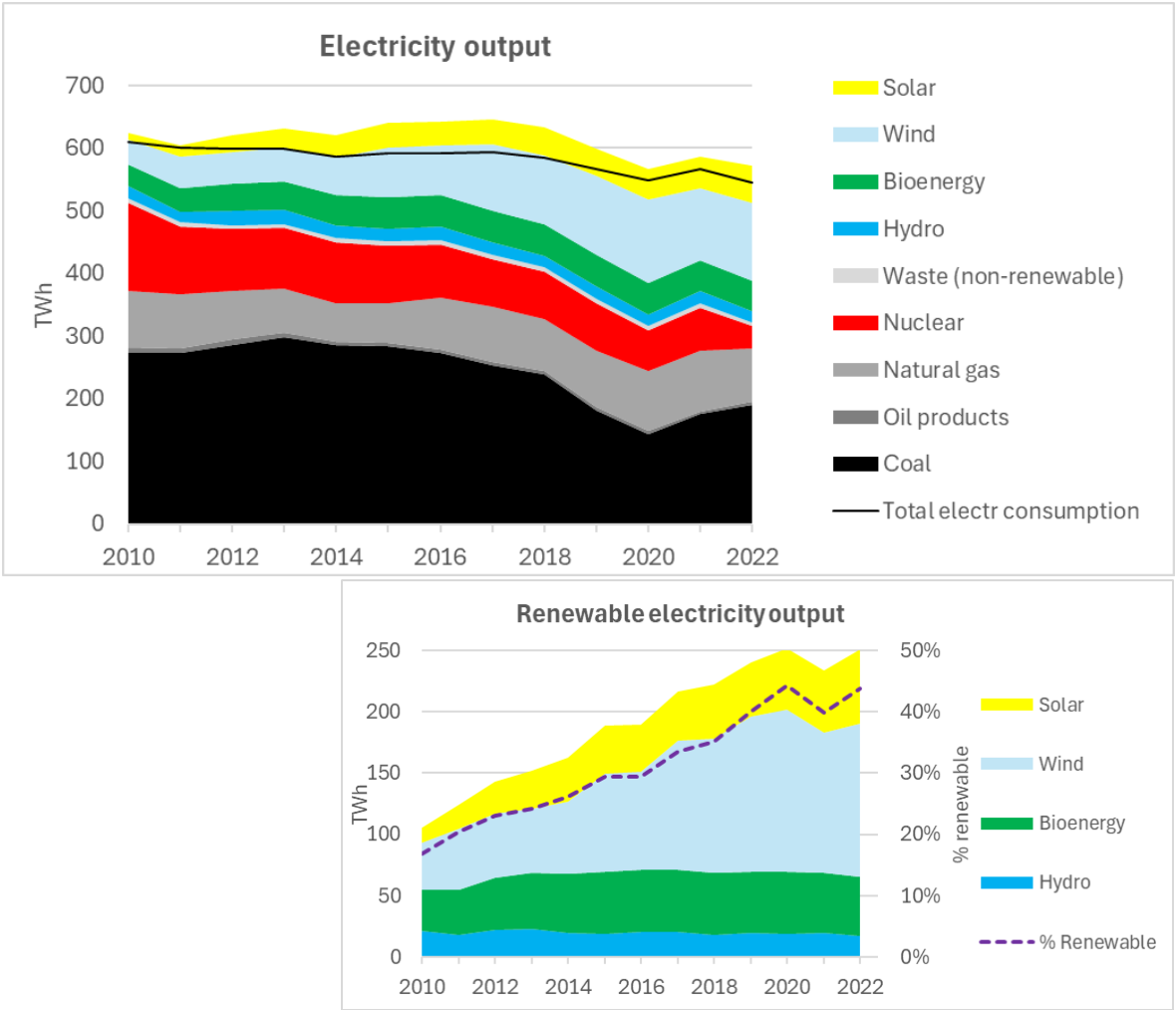

Figure 5: Evolution of the electricity mix in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Natural gas represented 14% of power production in Germany in 2010, at 90 TWh. This went down to 63 TWh in 2015. However, after 2015 natural gas power increased again to 90-100 TWh, thereby compensating for some of the reductions in coal power, but also increasing Germany's reliance on gas imports from Russia. Imports from Russia stopped in 2022.

The share of **renewable** electricity in power production increased steadily from 17% in 2010 to 44% in 2022. **Wind** power has consistently grown up to 23% of German power production in 2020 (132 TWh). Levels seem to have stabilized in the past few years. **Solar** power increased steadily from 12 TWh in 2010 to 60 TWh in 2022, which is 11% of German power production.

Biomass-based electricity increased from 34 TWh in 2010 to 50 TWh in 2014 and has stabilised since, currently representing 8.8% of electricity production. As shown in **Figure 6**, most bio-electricity is produced from biogas. **Hydropower** has been fairly constant around 20 TWh (3.5% of electricity consumption).

Typically, 5 to 8% of German electricity production was exported to neighbour countries.

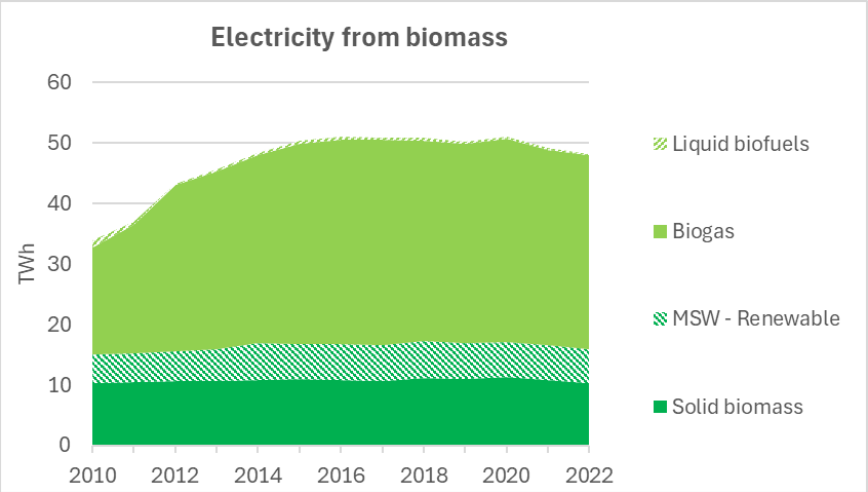

Figure 6: Evolution of electricity from biomass in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

The following figure shows the distinction between electricity produced in electricity-only plants and combined heat and power (CHP) plants for different types of energy carriers. Germany has a good tradition in gas-based CHP, but over 90% of coal power and 100% of nuclear power is produced in electricity-only plants, meaning that heat is condensed away.

On the contrary, 70% of electricity from biomass (particularly biogas) is produced in CHP plants, which also produce useful heat. Since 2012, major efforts have been made and incentivised to operate biogas plants in a more flexible way, in order to balance fluctuating electricity production from wind and PV.[22]

[22] https://biogas.fnr.de/biogas-nutzung/stromerzeugung/stand-der-flexibilisierung-von-biogasanlagen

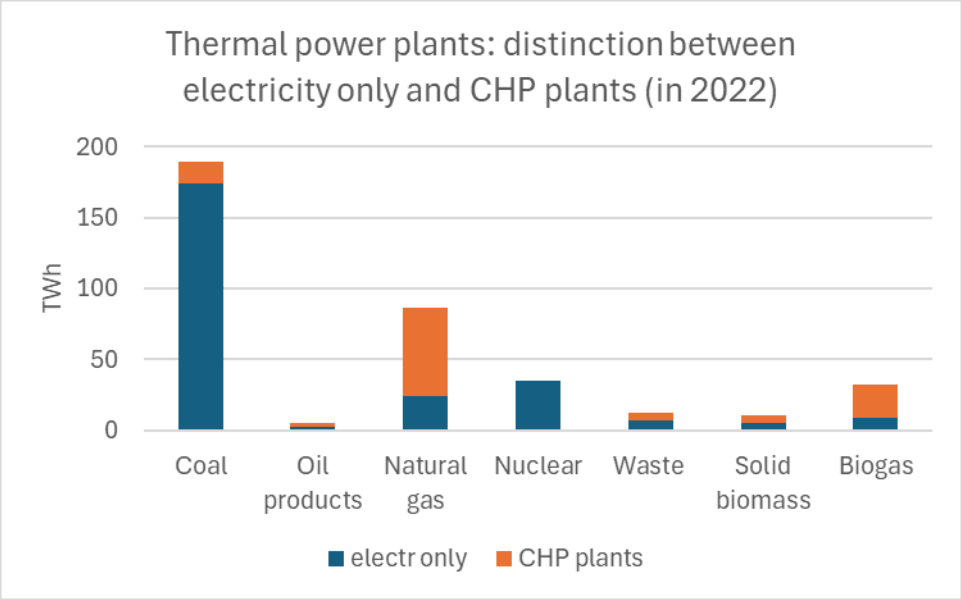

***Figure 7**: Electricity produced from electricity only vs CHP plants in Germany in 2022 (data source: IEA (2024) World Energy Balances and Renewables Information)*

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)[23]
- Renewable Energy Sources Act (EEG) 2017 – operational subsidy (auction/bidding system)
- Renewable Energy Sources Act (EEG) 2021
- Renewable Energy Sources Act (EEG); eight versions since 2000[24]
- Biomass electricity sustainability ordinance (BioSt-NachV) 2009[25]
- Biomass ordinance 2001[26]
- Climate Action Plan 2050[27]

The **Renewable Energy Sources Act** ("Erneuerbare Energien Gesetz") is the main scheme supporting the production of electricity from renewable energy sources and mine gases. It 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

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

[24] https://www.clearingstelle-eeg-kwkg.de/eeg2023

[25] https://www.gesetze-im-internet.de/biost-nachv_2021/BioSt-NachV.pdf

[26] https://www.gesetze-im-internet.de/biomassev/BiomasseV.pdf

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

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. Since 2023, EEG costs are borne by the federal budget.

The big but also costly asset of the EEG has been the guaranteed remuneration for electricity over 20 years, providing significant security to investors and operators. This has caused specifically a boom of biogas plants over many years. Until 2030 around 3000 biogas plants, around one third of the plants currently in operation, will no longer receive this guaranteed remuneration. Their future is uncertain, as the current EEG incentivizes only plants based on manure, as well as plants producing electricity in a highly flexible way, as an effort to balance fluctuating renewable energies such as wind and PV. The auction system, only offering very limited quotas for bioenergy, has been unattractive for biomass in recent years.

The EEG is supplemented by the **Biomass Ordinance** (Biomasseverordnung – BiomasseV)[28] and the **Biomass Electricity Sustainability Ordinance** (Biomassestrom-Nachhaltigkeitsverordnung – BioSt-NachV)[29] 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 with a phasing out support for plants in operation before 2013.

Next to the EEG there is the **Combined Heat and Power Act** (Kraft-Wärme-Kopplung-Gesetz – KWKG)[30] 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.

[28] https://www.gesetze-im-internet.de/biomassev/BiomasseV.pdf

[29] https://www.gesetze-im-internet.de/biost-nachv_2021/BioSt-NachV.pdf

[30] https://www.gesetze-im-internet.de/kwkg_2016/KWKG_2023.pdf

HEAT/FUEL CONSUMPTION

Figure 8 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 74% dominated by fossil fuels, mainly natural gas and oil. The share of oil is steadily decreasing, while natural gas has actually increased again since 2014, representing 50% of fuel/heat consumption. The direct use of biomass was relatively stable around 470-500 PJ in the period 2014-2020 but has increased somewhat in 2021 and 2022 up to 567 PJ. It now represents 13% of fuel/heat consumption, but the lion share of renewable heat provision. Solar thermal systems provide 0.8% of heat.

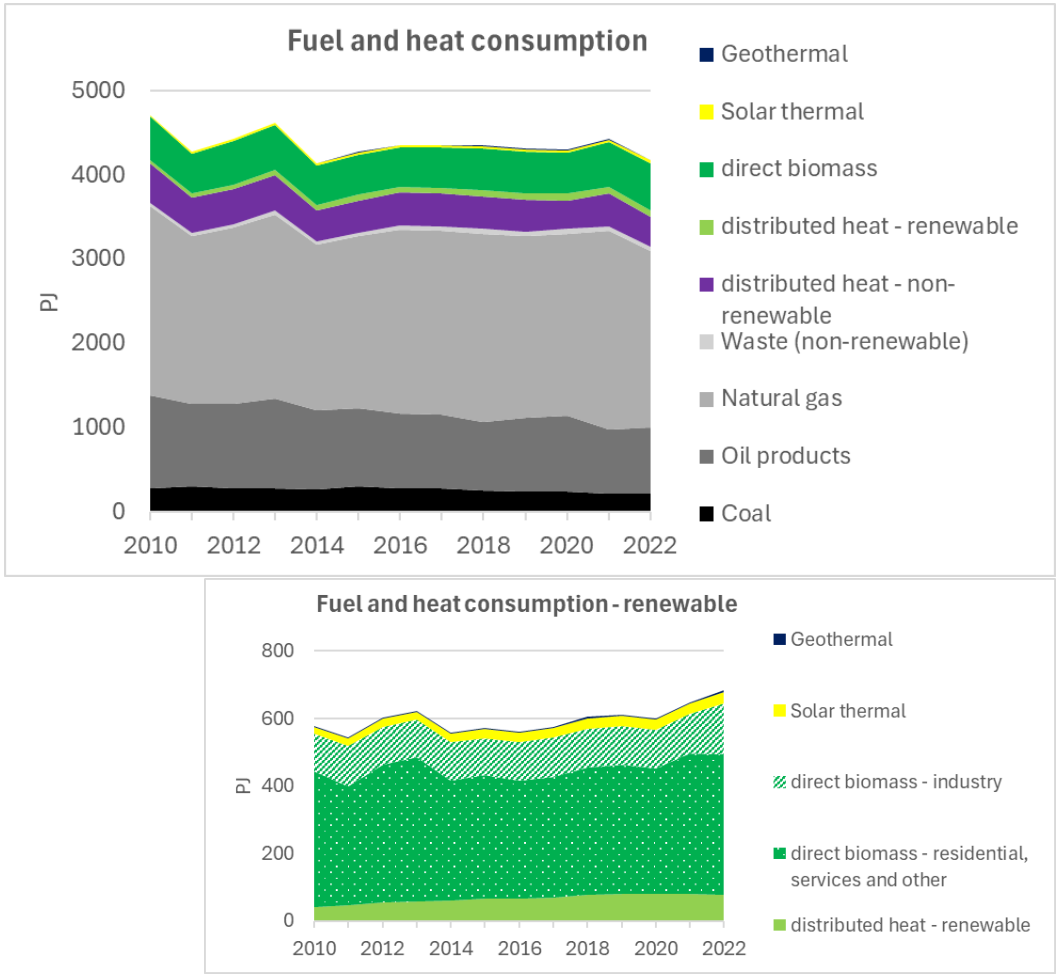

***Figure 8**: Evolution of fuel and heat consumption in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)*

Heat output generated and sold by CHP plants and heat plants (e.g., through district heating) represents around 10% of fuel/heat provided. Figure 9 shows that this is still for more than 70% 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 slightly increases, now reaching 18% of heat output.

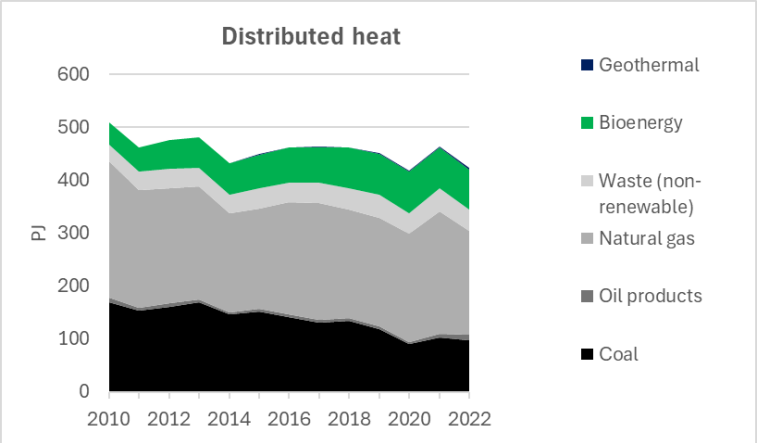

Figure 9: Evolution of fuels for heat output in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Policy framework

There is a range of measures and programmes in force to reduce the demand for heating and cooling, to reduce the climate impact and to increase the share of renewable energies. As one key measure, the Building Energy Act has been enforced in 2024[31], requiring a minimum share of renewable energy when installing new heating systems. For older buildings, transitions measures are applied. For biomass these regulations do not provide new opportunities, as biomass-based heating systems are only accepted in older buildings. The reasoning behind these provisions refers to the limitations of biomass availability in Germany, the issue of local emissions with biomass heating systems and the GHG neutrality of biomass.

[31] https://www.bundesregierung.de/breg-de/aktuelles/neues-gebaeudeenergiegesetz-2184942

TRANSPORT

Figure 10 shows an overview of the energy used in transport in Germany, split up by different fuels/energy carriers.

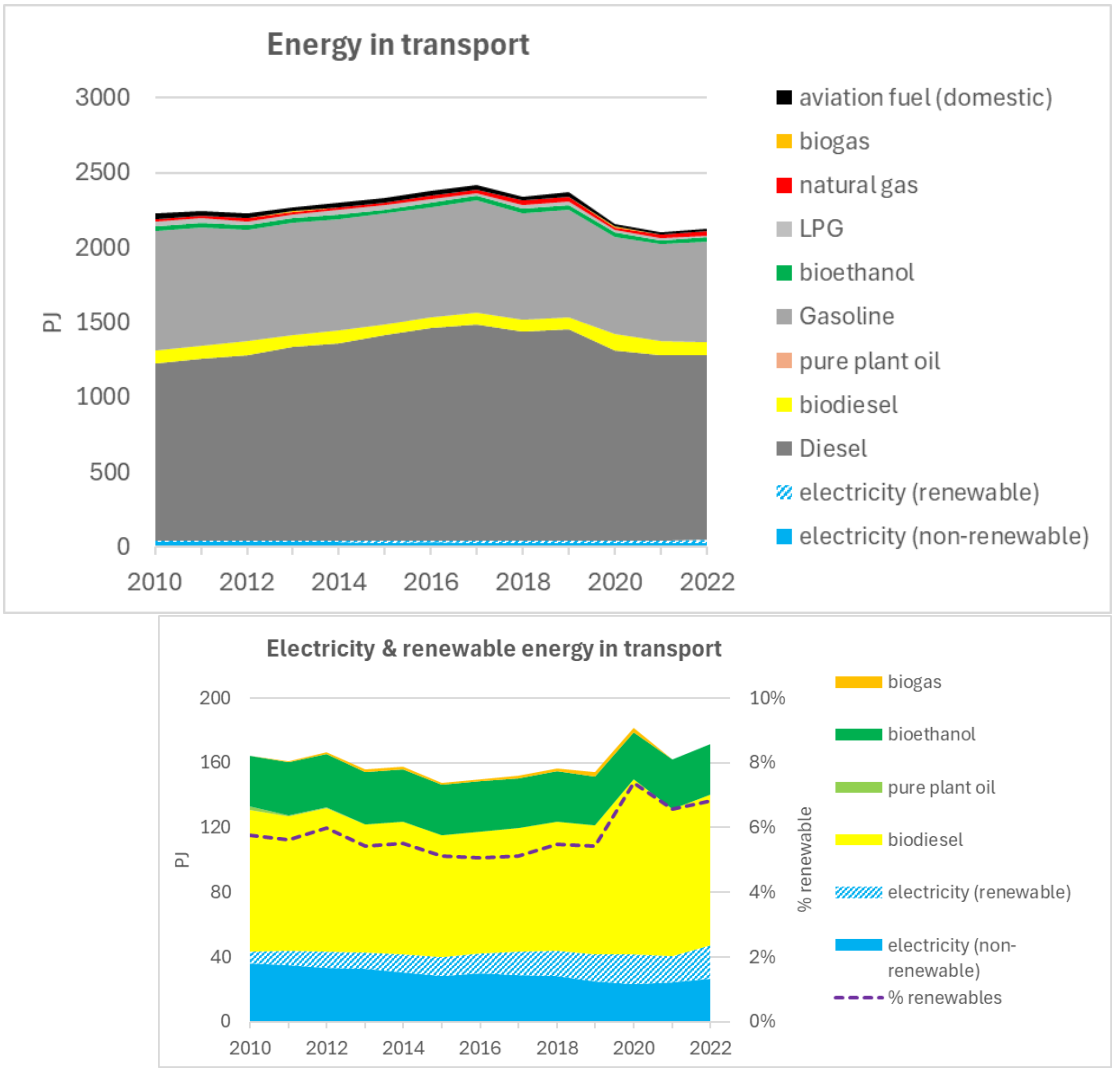

Figure 10: Evolution of transport fuels in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

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, biodiesels 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, see 2021 Country Report. This brought Germany at the forefront of transport biofuels introduction in Europe. In the following years focus shifted to general blending and the use of pure biofuels almost completely disappeared. Levels of biodiesels stabilized around 80 PJ in the period 2011-2019 (5-6% of diesel fuels, by energy, which represents a broad application of B7). In 2020 there was a step change in biodiesels up to 108 PJ, likely due to an increased use of HVO which has no blending limits in diesel fuel. In the years after there seems to be a stabilisation to a bit over 90 PJ.

Bioethanol blending in gasoline was introduced in 2004 and gradually increased to 33 PJ in 2012, see 2021 Country Report. This level has also stabilized since 2012. It represents a share of 4-4.5% by energy of gasoline fuels, which is consistent with a general application of E5 and some (limited) use of E10.

There is also some natural gas use in the German vehicle fleet, around 1.5% of transport fuels.

Electricity (which is ~45% renewable) represents a share of 2.3% of total transport energy use. This is mostly in rail - the use of electricity in road vehicles is still limited in 2022 (0.4% of total transport energy use) but can be expected to grow in the coming years.

Policy framework

The main relevant policy instruments behind these evolutions are:

- National implementation of RED I and RED II[32]
- Federal Immission Control Act (BImschG)[33]
- 38th Ordinance to implement BImSchG[34]
- National Hydrogen Strategy 2020[35]
- Biofuel sustainability ordinance (Biokraft-NachV) 2021[36]

The GHG emission reduction target in transport for 2024 is 9.25 %, increasing to 25 % in 2030. There are minimum targets for advanced biofuels (0.4% 2024 < 2.6% in 2030) and sustainable aviation fuels (which do not include biofuels in Germany; 0.5% in 2026 < 2% in 2030) and caps for crop-based as well as UCO- and animal-fat based biofuels. This is complemented by legislation to guarantee the sustainability of biofuels.

Today, regarding the overall set targets to significantly reduce GHG emissions on EU and national levels (e.g., by the European Green Deal[37], National Climate and Energy Plan 2050 [NECP][38]), 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 50% by 2030, compared to 2005 levels, as set in the Effort Sharing Regulation (ESR).[39] Although Germany has already taken comprehensive climate measures, further national efforts are required to achieve the set goal of CO_2 savings.

[32] https://ec.europa.eu/jrc/en/jec/renewable-energy-recast-2030-red-ii

[33] https://www.gesetze-im-internet.de/bimschg/BImSchG.pdf

[34] https://www.gesetze-im-internet.de/bimschv_38_2017/38._BImSchV.pdf

[35] https://www.bmwi.de/Redaktion/EN/Publikationen/Energie/the-national-hydrogen-strategy.html

[36] https://www.gesetze-im-internet.de/biokraft-nachv_2021/Biokraft-NachV.pdf

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

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

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

The measures for GHG emission targets are specified in the Climate Action Programme 2030.[40] With the Climate Action Plan[41], Germany sets a binding target saving of at least 40-42% of GHG emission reduction, compared to 1990, in the transport sector. This translates to 98 to 95 Mt CO_{2eq} in 2030.[42]

Huge imports of presumably falsely declared UCO-based advanced biofuels have had significant impact on the German markets for biofuels and GHG quotas in 2024.

During the last few years, Germany's public debate has been focusing on electric mobility, battery-powered vehicles, Power-to-X (PtX), and hydrogen. Regarding transport in the agricultural/forestry sector, tax relief for biofuels ended in 2021. There is a renewed interest in this sector.

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 supports the use of liquefied natural gas (LNG) for heavy-duty transport and waterborne application. The application of hydrogen as transport fuel is one of the keys within the National Hydrogen Strategy that was published in June 2020 and updated in 2023.[43]

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

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

[42] https://www.bmel.de/SharedDocs/Downloads/DE/_Landwirtschaft/Klimaschutz/Klimaschutzprogramm2030.pdf?__blob=publicationFile&v=3

[43] https://www.bmbf.de/bmbf/de/forschung/energiewende-und-nachhaltiges-wirtschaften/nationale-wasserstoffstrategie/nationale-wasserstoffstrategie_node.html

GAS CONSUMPTION AND THE ROLE OF BIOGAS/BIOMETHANE

Natural gas is one of the major types of energy in Germany, representing 25% of total energy supply in 2022. **Figure 11** below shows the different users of natural gas. The most important gas users in 2022 are the residential sector (31%), industry (29%), energy plants (24%) and the services sector (14%). Overall, natural gas plays an important role in all these sectors, as was discussed in the previous chapters.

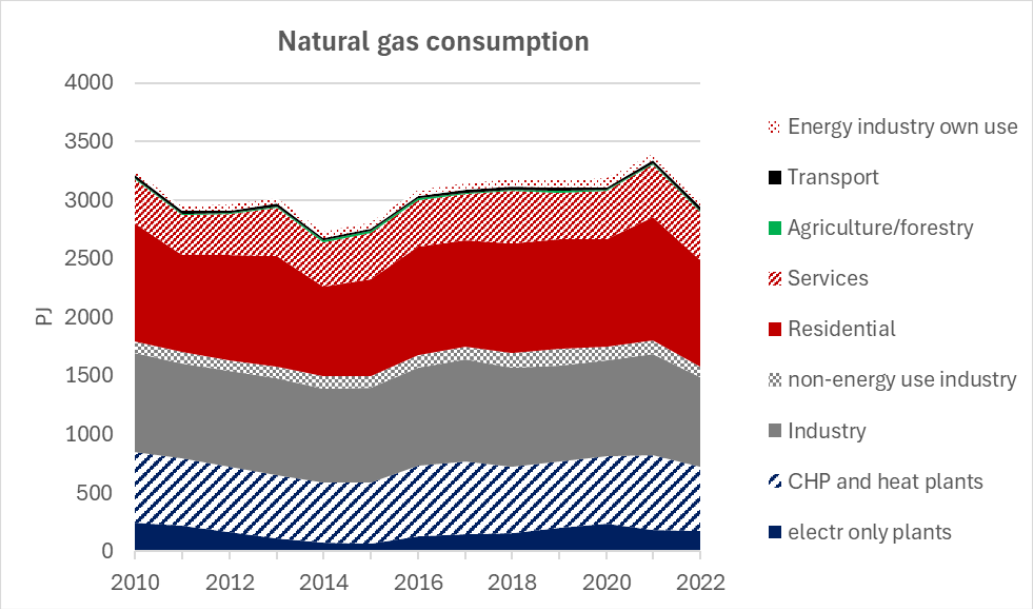

Figure 11: Evolution of gas consumption in different sectors in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Germany has been one of the pioneers in the deployment of biogas. When counted together, the different uses of biogas represent 10% of gas consumption. The main increase of biogas happened between 2005 and 2015, with levels stabilizing afterwards. Only in recent years has there been a limited increase.

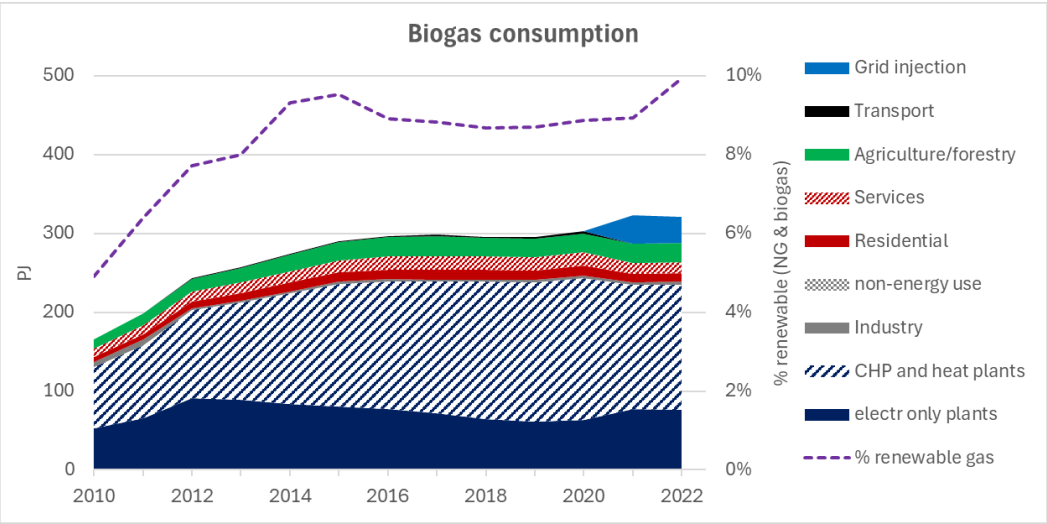

Figure 12: Evolution of biogas consumption in Germany 2010 - 2022, compared to overall gas consumption (data source: IEA (2024) World Energy Balances and Renewables Information)

Most biogas is used in CHP plants. Some biogas is now also upgraded to biomethane to be injected into the natural gas grid – in 2022, this represented 1.2% of gas consumption from the grid.

The main driver for biogas in the past decade has been the Renewable Energy Sources Act (EEG), supporting the production of electricity from renewable energy sources.

FINAL ENERGY CONSUMPTION IN DIFFERENT SECTORS (EXCL TRANSPORT)

Final Energy consumption in industries

Figure 13 shows energy consumption (fuels, heat and electricity) in industries. Electricity use is for broad purposes, including processes, machineries, electric appliances, lighting, and in some cases also for heating and/or cooling. For the renewable share of electricity consumption, we consider the German electricity mix.

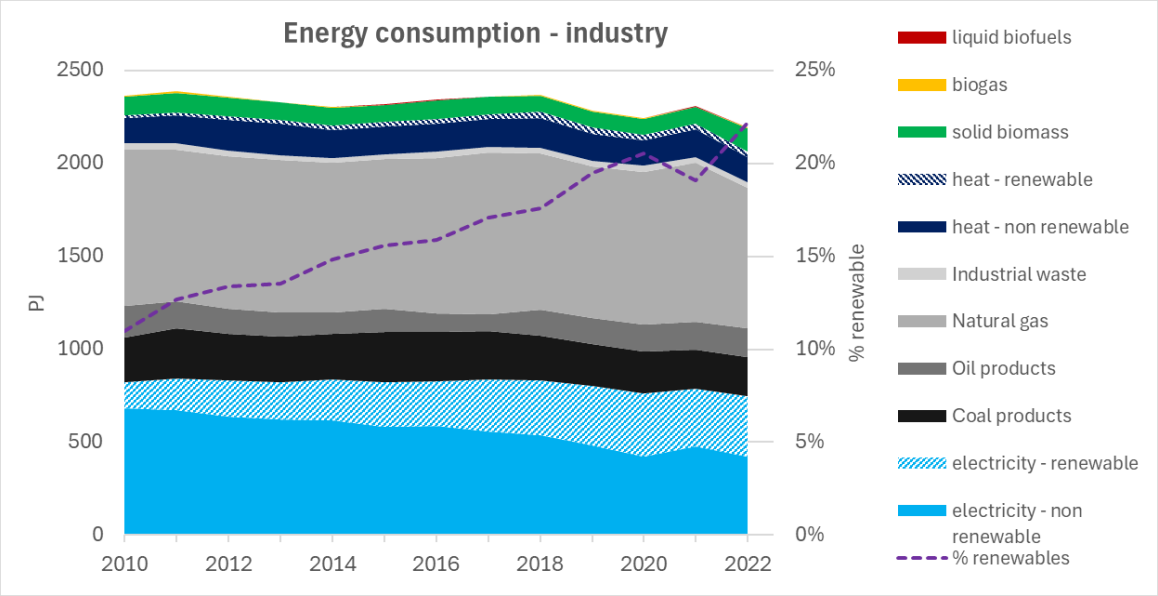

Figure 13: Evolution of final energy consumption in industries in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

In industries, electricity represents around 34% of final energy consumption, so the role of fuels is still substantial, with a particularly high reliance on natural gas. This made German industry very sensitive for the natural gas price hikes in 2022. Overall, about 22% of final energy consumption in industries is from renewable sources: 15% through renewable electricity, 6% through solid biofuels and 1.5% through renewable distributed heat.

For comparison, **Figure 14** shows the **non-energy use** of fossil resources in industries, e.g., for the production of chemicals. 82% of oil product consumption, 11% of natural gas consumption and 7% of coal consumption in German industries is for non-energy purposes.

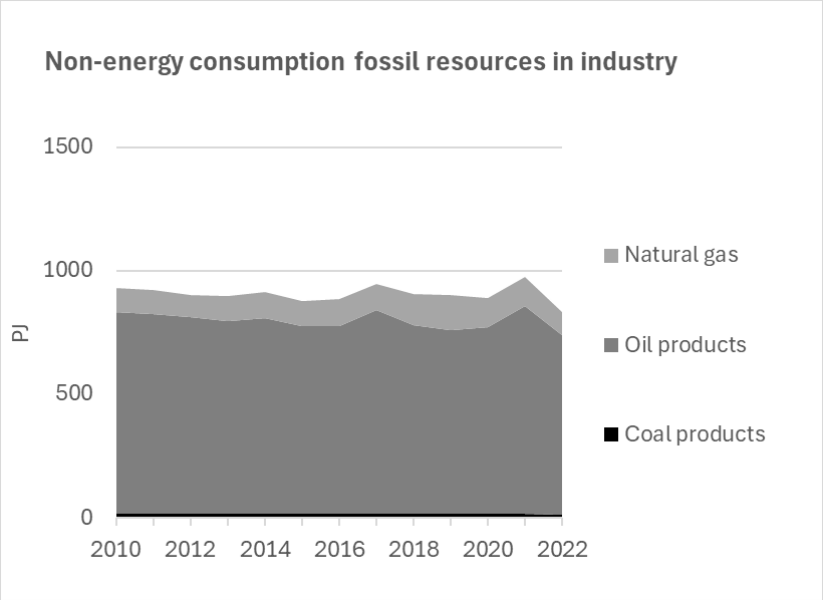

Figure 14: Evolution of non-energy use of fossil resources in industries in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Final Energy consumption in the residential sector

Figure 15 shows energy consumption (fuels, heat and electricity) in the residential. Electricity use is for broad purposes, including electric appliances, lighting, and partly also for heating and cooling (e.g. in heat pumps). For the renewable share of electricity consumption, we consider the German electricity mix.

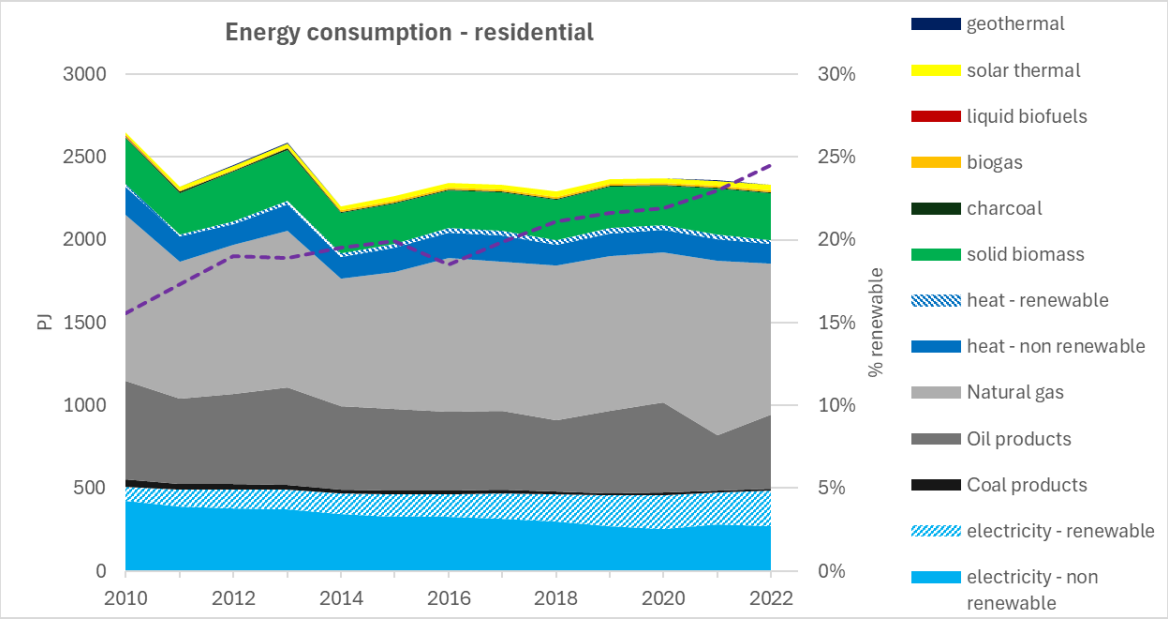

Figure 15: Evolution of final energy consumption in the residential sector in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Electricity represents a stable share of around 20% of final energy consumption in the residential sector, so the role of fuels to provide heat is substantial. In this sector there is also a heavy reliance on natural gas, but also oil products are still important. About 25% of final energy consumption in residential applications is from renewable sources, split between bioenergy (13%), renewable electricity (9%), solar thermal heat (1.4%) and renewable distributed heat (1.1%).

Final Energy consumption in commercial and public services

Figure 16 shows energy consumption (fuels, heat and electricity) in commercial/public services. Electricity use is for broad purposes, including electric appliances, lighting, servers, and partly also for heating and cooling (e.g. in heat pumps and air conditioning). For the renewable share of electricity consumption, we consider the German electricity mix.

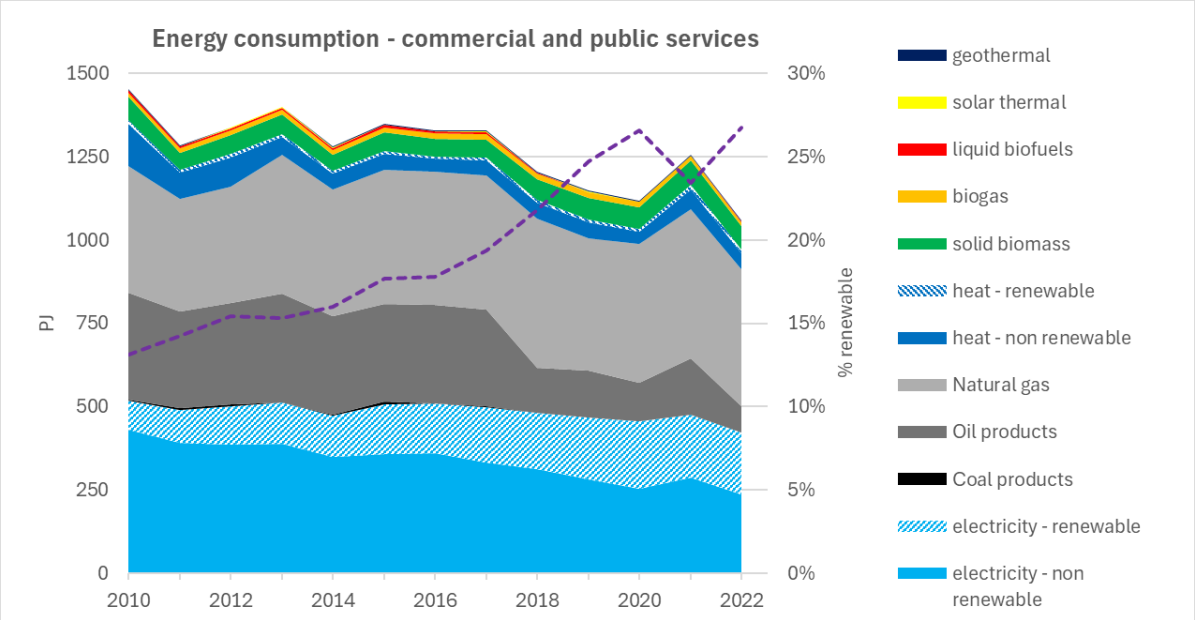

Figure 16: Evolution of final energy consumption in commercial and public services in Germany (data source: IEA (2024) World Energy Balances and Renewables Information)

Energy consumption by commercial and public services is relatively modest in Germany, as compared to the residential sector (around 1100 PJ compared to 2400 PJ residential). In commercial and public services, electricity plays a more important role than in households at 40% of energy consumption. Still fuels - particularly gas - remain important. There is a clear decreasing trend of oil products in these sectors. The direct use of biomass is limited, as well as the role of distributed heat (which is partly based on biomass).

About 27% of final energy consumption in commercial and public services is from renewable sources, predominantly through renewable electricity (17.5%), and smaller shares of solid biomass (6.5%), biogas (1.3%) and renewable distributed heat (1%).

COMPARISON WITH RENEWABLE ENERGY TARGETS

According to Eurostat[44], the following renewable energy shares in *gross final energy consumption* were reached.

Table 5: Share of renewables in different sectors in Germany, according to Eurostat, and compared to the 2020 target

	2005	2010	2015	2020[45]	*2020 target*	2022	*2030 target*
Overall share	7.2%	11.7%	14.9%	19.1%	*18%*	20.8%	…
In heating & cooling	7.7%	12.1%	13.4%	14.5%	*15.5%*	17.5%	*50%*[46]
In electricity	10.6%	18.2%	30.9%	44.2%	*38.6%*	47.6%	*80%*
In transport	4.0%	6.4%	6.6%	10.0%	*10%*	9.9%	*30%*[47]

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

In 2020, Germany reached its overall renewable energy target, and went even slightly beyond, particularly for renewable electricity. Physical levels of renewable energy in German transport have not seen major increases up to 2019 – 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. Through a temporary increase of biodiesels in 2020, the 2020 target for transport was reached. Towards 2022 there is some further increase in renewables, but overall limited. With increased ambitions at EU level to double the share of renewable energy by 2030 compared to 2020, urgent action will also be needed in Germany.

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.

[44] https://ec.europa.eu/eurostat/databrowser/view/sdg_07_40/default/table?lang=en

[45] Substantial impact of COVID measures on final energy consumption in 2020 (particularly in industry and transport), somewhat inflating the shares of renewables.

[46] Of grid connected heating and cooling

[47] According to RED2 methodology

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.[48] At the same time 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)[49], the Ministry for Economy Affairs and Energy (BMWK)[50], and the Ministry of Food and Agriculture (BMEL) which has the lead for bioenergy research on the federal level[51]. 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, BMWK and BMEL coordinate their R&D funding activities in the 8th Energy Research Programme[52]. In addition, the Ministry of Environment (BMUV) and the Ministry of Transport (BMVI) pursue activities relevant for bioenergy research, the BMVI with a large programme on renewable fuels for transport.[53]

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 and other ministries. 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.[54] 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

[48] 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

[49] https://www.fona.de/en/index.php

[50] https://www.energetische-biomassenutzung.de/de

[51] http://international.fnr.de/renewable-resources/bioenergy/

[52] 2024 Federal Government Report on Energy Research: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/240716-bundesbericht-energieforschung-2024.html

[53] https://erneuerbarekraftstoffe.de/

[54] https://www.dbfz.de/en/research.html

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

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).

The federal government has been working on a new National Biomass Strategy (NABIS) since 2022. Although a Key Issues Paper has been published in October 2022[55], the strategy is not yet finalised. Key aims are sustainability, climate protection and biodiversity. For biomass use the food first principle is crucial. In the non-food sector biomaterials have priority over bioenergy and the cascading approach should be followed. The main focus lies on biogenic wastes and residues, which are limited, however.

A Bioeconomy Strategy was approved in early 2020[56], with the Ministries of Research and Agriculture in the lead. An Implementation Plan is under development, emphasising the need for circularity. Feedstock potentials, R&I promotion, development of new markets for innovative biobased products and services, development of biobased value chains, use of the bioeconomy potential for the development of rural regions, and the digitalisation of bioeconomy are issues to be addressed.

The federal government does not see any significant additional bioenergy uses in the future.

In the heating sector, the contribution of bioenergy has been constant in recent years. With the focus on other renewable energies and heat pumps, its share will decrease in the future.

Electricity production from bioenergy has also stagnated in recent years. Especially the nearly 9000 existing biogas plants are under pressure. Flexible power provision from biomass is today possible in many biogas plants, however there is still lack of incentives, to fully use the flexible generation. With guaranteed electricity prices phasing out during the next years and a difficult general situation in agriculture there is a fear that up to one third of the plants will stop operating by 2030. The biomethane option, also promoted on EU level, is only feasible for larger plants. The low CO_2 certificate prices in 2024 have undermined the bankability of many new projects.

[55] https://www.bmuv.de/download/eckpunkte-fuer-eine-nationale-biomassestrategie-nabis

[56] https://www.bmel.de/SharedDocs/Downloads/EN/Publications/national-bioeconomy-strategy-summary.pdf?__blob=publicationFile&v=6

Transport sector: The use of biofuels is stagnating. As also the electrification of transport is progressing slower than forecasted, the gap between GHG reduction targets and the actual market situation is increasing. Fraud with UCO imports has put further pressure on the market.

The main government focus is on electrification of transport, as well as the use of hydrogen. 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.), where the government has a clear priority for renewable fuels. Both government and stakeholders have high expectations in green hydrogen. Expected cost reductions have not materialised so far. Additionally, carbon dioxide removal (CDR) has become an increasing but controversial issue in the debates.

LINKS TO SOURCES OF INFORMATION

Renewable energy statistics: https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen

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/

BMWK dossier Renewable Energies: https://www.bmwk.de/Redaktion/DE/Dossier/erneuerbare-energien.html

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