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Germany 2020

Energy Policy Review

International Energy Agency

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INTERNATIONAL ENERGY AGENCY

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Foreword

The International Energy Agency (IEA) has conducted in-depth peer reviews of its member countries' energy policies since 1976. This process not only supports energy policy development, but also encourages the exchange of and learning from international best practices and experiences. In short, by seeing what has worked – or not – in the "real world", these reviews help to identify policies that achieve their objectives and bring concrete results. Recently, the IEA has moved to modernise the reviews by focusing on some of the key energy challenges in today's rapidly changing energy markets.

Germany is an important and active member of the IEA. I am grateful to Peter Altmaier, Federal Minister for Economic Affairs and Energy, for his collaborative spirit and commitment to building a secure and sustainable energy future. Together, we co-organised the first Global Ministerial Conference on System Integration of Renewables in Berlin in October 2019. The event brought together government ministers, industry chief executives and other high-ranking officials from around the world to share best practices and innovative ideas to help fully grasp the opportunities of wind and solar energy.

Since the IEA review of German energy policies in 2013, the Energiewende has remained the defining feature of the country's energy landscape. In place for nearly a decade, the Energiewende is a major plan for transforming the German energy system, making it more efficient and supplied mainly by renewable energy sources. It aims to phase out electricity generation from nuclear power by the end of 2022.

To date, the Energiewende is clearly visible in electricity generation, where it has been effective at increasing the share of renewable energy supply. Still, despite progress on lowering overall emissions, Germany is struggling to meet its near-term targets. This is in large part because of uneven progress across sectors, with notable challenges in transport and heating. Now, the government must refocus its efforts to achieve stronger emissions reductions in these other sectors. The IEA welcomes the recently adopted climate action plan, which includes a carbon price in the transport and heating sectors, as an important step in the right direction.

Energy security remains a focus area for the IEA, and I am pleased to observe that Germany has maintained a high degree of oil, natural gas and electricity supply security. As the nuclear and coal phase-outs increase Germany's reliance on natural gas, it will be increasingly important for the country to continue efforts to diversify its gas supply options, including through the import of liquefied natural gas.

I strongly believe that both policy and regulatory reforms can move Germany towards a cost-efficient, equitable and sustainable path to meeting its highly ambitious energy transition goals. It is my hope that this report will help Germany as it undertakes this crucial endeavor.

Dr Fatih Birol

Executive Director

International Energy Agency

ENERGY INSIGHTS

ENERGY SYSTEM TRANSFORMATION

ENERGY SECURITY

ANNEXES

LIST OF FIGURES, TABLES AND BOXES

Figures

Tables

Boxes

1. Executive summary

Overview

Since the 2013 International Energy Agency (IEA) review of German energy policies, the Energiewende continues to be the defining feature of Germany's energy policy landscape. In place for nearly a decade, the Energiewende is a major plan for transforming the German energy system into a more efficient one supplied mainly by renewable energy sources and without electricity generation from nuclear by the end of 2022. As such, the Energiewende is meant to move Germany towards a low-carbon, nuclear-free energy system by the middle of the century.

Over the last four decades, Germany's energy supply has shifted from a clear dominance of coal and oil to a more diversified system. Nuclear energy, first introduced in the 1970s, is being replaced by more renewables, in line with Germany's energy transition targets. Furthermore, coal, which represents the largest source for power generation today, is planned to be fully phased out by 2038.

Still, Germany is struggling to achieve its climate change ambitions, and is not on track to meet its near-term emissions reduction targets. The growth in electricity generation from renewables has lowered emissions, but the nuclear phase-out as well as higher electricity exports have offset some of the emissions benefits. That said, the government's planned coal phase-out could help reset the country on a path to achieving its longer-term emissions targets in the electricity sector.

Nonetheless, to date, the electricity sector has been shouldering a sizeable share of the Energiewende's costs and progress. Now, the government must refocus its efforts to achieve stronger emissions reductions in other sectors, notably transport and heating. The Climate Protection Programme 2030 recently adopted by the German government, including a carbon price in the transport and heating sectors, is an important step in the right direction. The plan is also mindful of the distributional impacts of climate policies and aims to ensure a level playing field across sectors and stakeholders. Both policy and regulatory reforms can help Germany achieve a cost-efficient, equitable and sustainable pathway to meeting its highly ambitious energy transition goals.

Emissions targets

Germany's national climate change strategy is defined in the Climate Action Plan 2050, which sets out a longer-term pathway for sector-specific emissions reductions, as part of the Energiewende. Compared with the base year of 1990, the key goals are to achieve at least a 40% cut in greenhouse gas (GHG) emissions by 2020, 55% by 2030, 70% by 2040 and 80-95% by 2050, at which point the country expects to be mostly GHG-neutral. These targets are complemented with short- and medium-term targets for energy consumption and energy efficiency, and renewable energy supply.

As a member of the European Union (EU), Germany's climate policy is guided by the framework of EU energy and climate policies: the 2020 energy and climate package and the 2030 energy and climate framework. Large combustion facilities in the power and industry sectors are part of the EU Emissions Trading System (ETS), whereas non-ETS emissions are subject to the Effort Sharing Decision until 2020 and the Effort Sharing Regulation from 2021 to 2030.

To reach the overall GHG emissions reduction target for 2020, the federal government adopted the 2020 Climate Action Programme in December 2014. The key policy strategy areas described in the programme are the National Action Plan on Energy Efficiency, the Energy Efficiency Strategy for Buildings, transport sector measures (including mileage-based charges for road freight vehicles and federal funds for long-distance public transport), and measures in the electricity sector (to increase renewable energy, modernise fossil fuel power plants and develop more co-generation plants[1]).

Despite progress on lowering overall emissions, Germany is struggling to meet its near-term targets, in large part due to uneven progress across sectors, with notable challenges in transport and heating. Even with a rapid increase in renewable electricity generation, Germany's total emissions have not experienced commensurate reductions. As of 2018, Germany had reduced its total GHG emissions by around 31% compared with 1990. So Germany remains far off its 2020 emissions target of a 40% reduction.

As such, Germany needs to expand and prepare new policies and measures that can help it reach its national GHG emissions reduction targets in a cost-effective and sustainable way. Notwithstanding the nuclear phase-out, Germany's focus on renewable power and a planned coal phase-out (along with its participation in the EU ETS) will help ensure progress in the power sector. However, additional policies are needed to support emissions reductions outside of the power sector, notably in transport and heating.

More recently, in March 2019, the government formed a so-called climate cabinet, headed by the chancellor, to arrive at a consensus on a new package of emissions reduction measures to meet 2030 targets. Based on the climate cabinet's proposals, the government on 9 October adopted the Climate Action Programme 2030, which includes a phased carbon pricing system for certain sectors not covered by the EU ETS (heating and transport), a tax break and other increased incentives for energy-efficient building renovations, higher subsidies for electric vehicles (EVs), and greater public investment in public transport. The government also agreed to use some of the revenues from the new carbon pricing system to lower the costs for households and companies by providing tax relief and a reduction in fees on electricity prices. The package represents a clear step in the right direction towards Germany meeting its 2030 targets.

Electricity transition

To date, Germany's Energiewende is clearly visible in electricity generation, where it has been effective in increasing renewable electricity generation. While coal (mainly lignite)

[1] Co-generation refers to the combined production of heat and power.

remains the largest source of electricity, renewables have mainly replaced a large share of nuclear over the last decade. In 2017, wind power surpassed both nuclear and natural gas to become the second-largest source of electricity generation. Continued growth in renewables in line with Germany's energy and climate targets will require a number of measures for advancing electrification and system integration of renewables, including improvements to taxation and market regulation, and expansion of the transmission and distribution infrastructure, including improving its functionality.

As a core plank of the Energiewende, Germany plans to further expand the role of renewables in electricity generation. Specifically, in the 2010 Energy Concept, the country aimed for renewables to account for 35% of gross electricity consumption by 2020 and overachieved this with 38% in 2018 and 44% in the first half of 2019. The German government initially planned to further increase the share of renewables in electricity to 50% by 2030, 65% by 2040 and 80% by 2050. But according to the new coalition agreement of March 2018, as affirmed by the climate cabinet, the government is now planning to speed up the growth, to reach a share of 65% renewable electricity by 2030 (contingent on a corresponding expansion in grid capacity).

Reforms to the Renewable Energy Sources Act in 2014 and 2017 created a welcome overhaul in renewable energy funding towards more competition and greater cost efficiency, limiting the previous system of fixed funding rates, which became too costly and less necessary as the deployment costs of wind and solar came down rapidly. The renewable energy sources with the largest capacity additions – onshore and offshore wind energy, large photovoltaic systems, and biomass – are now required to compete in auctions, where only the cheapest offers are awarded contracts.

Germany has taken steps to reform its electricity market regulation to ensure smoother system integration of variable renewable generation, notably with the passage of the Act on the Further Development of the Electricity Market in 2016. Still, more challenges loom as renewable power is poised for additional growth.

Most wind capacity is located in northern Germany, whereas most demand comes from metropolitan and industrial areas in the south and west of the country. Due to increased generation from wind and solar, network constraints preventing transmission from the north to the south, delays in grid expansion, and the fact that Germany has only one bidding zone, northern states are facing power surpluses and southern ones are experiencing deficits, an imbalance that will worsen as the last of the country's commercial nuclear power plants in the south and northwest close and wind comes online in the north. The imbalance has resulted in "re-dispatch" measures in the south (where grid operators order power stations to ramp up output to compensate for procured electricity that cannot make it south) and curtailment in the north (where grid operators order generators to shut down to avoid congestion), costing consumers hundreds of millions of euros annually.

Connections to carry wind power from the north to the south are insufficient. Public opposition to north-south high-voltage transmission lines has slowed down construction of new overhead lines considerably and eventually forced costlier underground construction of interconnectors; public opposition remains an impediment to the siting of necessary infrastructure. Delays to grid expansion experienced thus far have generated significant congestion management costs. As such, grid expansion is a stated priority for the government.

Beyond nuclear, the government also has a strategy to phase out the use of coal-fired power generation to help meet emissions targets. To reach a broad social consensus on the coal phase-out plan, the federal government established a Commission on Growth, Structural Change and Employment in June 2018. The commission presented its report in January 2019, with a recommendation to completely phase out coal power by 2038 at the latest. As sub-targets, the commission recommended decommissioning at least 12.5 gigawatts (GW) of coal-fired power plants by 2022 and 25.6 GW by 2030. Furthermore, the commission proposed that coal mining regions receive EUR 40 billion in transitional assistance.

As there is currently excess generation capacity, and the government has a target to decrease overall energy consumption, it is yet unclear how much and where new capacity will be needed to replace the capacity that will be phased out. Given the environmental and climate goals of the government, it is most likely that renewable capacity will need to be added to the generation mix to replace capacity closures (along with increased utilisation of gas-fired capacity), further supporting the case for an increased focus on transmission grids and system integration of renewables. Moreover, the government will also need to address recent social acceptance and permitting issues affecting Germany's onshore wind sector, as well as repowering of ageing wind facilities.

Beyond electricity

Despite Germany's progress and plans to achieve emissions reductions in the power sector, the government recognises that more progress is needed in other sectors, notably in heating and transport, in order to meet overall carbon reduction targets.

Transport, in particular, has been the biggest laggard on emissions reductions and the most significant impediment to Germany meeting its GHG targets. Moreover, Germany's heavy reliance on diesel vehicles in road transport has contributed to rising air pollution, especially nitrogen dioxide emissions.[2] In addition to efficiency improvements in line with EU requirements as well as promoting EVs, the Climate Action Plan 2050 also identifies local public transport, rail, cycling, walking and digitalisation as playing important roles in achieving climate targets in the transport sector. The government launched a task force on emissions reduction in the transportation sector, called the National Platform Future of Mobility, to make recommendations on addressing transport sector emissions. Moreover, the government has decided to implement a carbon price on transport emissions, which would raise fuel prices and help motivate improvements in transport efficiency.

Beyond transport, heating – which accounts for over 50% of final energy consumption and around 40% of emissions – remains a sector in which the government is still in the process of formulating a decarbonisation plan. Germany's heating sector is highly dependent on fossil fuels (25% oil heating in the residential sector, in part due to low taxation on heating oil), and a large share of co-generated district heating is produced from fossil energy sources. As a first step, increasing energy efficiency, not just in new buildings but also through higher rates of renovation, will be essential. Moreover, using more renewable energy in heating systems will form a critical plank of decarbonising Germany's heating sector. Given Germany's rapid growth in renewable electricity, there is an attractive

[2] According to the European Environment Agency, in the 28 EU member states, road transport contributed to 39% of total nitrogen dioxide emissions.

opportunity to both increase the direct role of renewables in heat generation and pursue sector coupling, to use more renewables-based electricity for heating. However, high electricity costs, driven by levies, charges and taxes (including the Renewable Energy Act surcharge to subsidise renewables) are impeding opportunities to use more electricity in the heating sector, especially in a context of low taxation on fossil fuels.

The Climate Action Programme 2030 contains important measures for the heating sector, such as tax relief for energy-efficient refurbishment of buildings; a premium for exchanging oil heaters for new, efficient heating systems; and the expansion of heat grids and district heating with a view to integrating renewable energy sources into heating networks (especially in densely populated areas). As the intended carbon tax will also apply to heating emissions, it will bolster existing energy efficiency efforts in the sector.

Energy security

Germany has diversified oil supply sources, a well-connected supply infrastructure, a liberal market and high oil emergency reserves that all contribute to maintaining the country's strong security of oil supply. More progress on fiscal incentives, such as subsidies and tax differentials for low-emissions vehicles and associated infrastructure, can further support Germany's oil security as well as the low-carbon transition by reducing demand for oil in the transport sector.

Germany has also ensured a relatively high level of natural gas supply security, despite a heavy reliance on imports (93% of supply). The Russian Federation is by far the largest gas exporter to Germany, followed by the Netherlands and Norway. Although the German government is focused on a massive expansion of renewables, the phasing out of both nuclear and coal generation will increase Germany's demand for natural gas in power generation, including as a backup fuel source for renewables; hydrogen derived from renewable sources holds potential as a longer-term solution. The uptick in demand will increase Germany's already-high call on natural gas imports. Moreover, at the same time that Germany's own production of gas is small and declining, its gas imports from European sources are also set to fall in the coming years, especially from the Netherlands, where production from the Groningen field is declining and due to fully terminate by 2022 at the latest. As a result, security of natural gas supply is a top concern for the government, and diversification of gas supplies – including through the direct import of liquefied natural gas (LNG) – will become more important. Notably, the increased use of natural gas in electricity generation, especially to meet peak electricity demand, will also increasingly tie electricity security to gas security.

Key recommendations

- ☐ Expand the scope and ambition of energy and climate policies beyond a focus on the electricity sector, especially to transport and heat, to achieve a genuine energy transition across all sectors.

- Ensure the timely expansion and upgrading of transmission lines in order to improve system operations and integrate larger amounts of variable renewable electricity. Expedite the process of permitting and building new transmission lines to meet future transmission needs.
- Adopt a more comprehensive approach to promoting reduced energy demand in transportation, including stronger incentives for cost-effective consumer adoption of alternative transport technologies and promotion of public and multi-modal transport.
- Reform and strengthen measures targeting an increased renovation rate of existing buildings to foster energy efficiency improvements.
- Bolster energy security through diversified gas imports, including LNG; ensure electricity security during the energy transition through flexibility and preparedness.
- Remove the barriers that hinder efficient sector coupling, by fostering a level playing field across end-use sectors, including by removing fossil fuel tax breaks; introducing carbon pricing in non-ETS sectors; and rebalancing taxes, levies and incentives, while fairly allocating costs and benefits across customer groups.

2. General energy policy

Key data

(2018 provisional)

TPES: 298.3 Mtoe (oil 32.8%, natural gas 24.0%, coal 22.5%, bioenergy and waste 10.1%, nuclear 6.6%, wind 3.2%, solar 1.6%, hydro 0.5%, geothermal 0.1%, electricity exports* -1.4%), -10.0% since 2008

TPES per capita: 3.6 toe/cap (IEA average [2017]: 4.1 toe)

TPES per unit of GDP: 81 toe/USD million PPP (IEA average (2017): 105 toe)

Energy production: 111.6 Mtoe (coal 33.7%, biofuels and waste 26.8%, nuclear 17.8%, wind 8.6%, natural gas 4.2%, solar 4.2%, oil 3.1%, hydro 1.4%, geothermal 0.2%), -16.2% since 2008

TFC (2017): 227.0 Mtoe (oil 41.5%, natural gas 24.4%, electricity 19.7%, biofuels and waste 6.7%, district heat 4.3%, coal 3.2%, solar heat 0.3%), +3.0% since 2007

*Electricity exports are counted as negative in TPES.

Country overview

Germany, whose full name is the Federal Republic of Germany, is located in Western Europe, with the Baltic and North Seas to the north and the Alps to the south. It is the fourth-largest country in the European Union (EU) by area, and the most populous. It shares borders with nine other European countries (Denmark, the Netherlands, Belgium, Luxembourg, France, Switzerland, Austria, the Czech Republic and Poland). Berlin is the capital and the largest city. Other large metropolitan areas include the Rhine-Ruhr area, Frankfurt, Hamburg, Munich and Leipzig.

Germany was one of the founding members of the European Economic Community in 1957 and the European Union in 1993. It is part of the Schengen Area and has been a member of the eurozone since it started in 1999. Germany is also one of the founding members of the Organisation for Economic Co-operation and Development (OECD), along with 19 other countries, and has been an International Energy Agency (IEA) member country since the agency was founded in 1974.

Germany's population stood at 82 685 827 in 2017 (World Bank, 2019). Population increased by 0.4% in 2017 – slightly higher than the EU average of 0.2% – driven by net migration, offsetting declines from natural births and deaths.

Germany has a social market economy with a highly skilled labour force, a large capital stock, a low level of corruption and a high level of innovation. It has the world's fourth-largest economy by nominal gross domestic product (GDP) and the fifth largest by purchasing power parity (PPP) (OECD, 2018a). It is also the world's third-largest exporter of goods (CIA, 2019).

Figure 2.1 Map of Germany

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international prontiers and boundaries and to the name of any territory, city or area.

Germany has been enjoying economic growth in recent years, driven in large part by strong domestic demand and exports. GDP growth in Germany's export-oriented economy slowed considerably in 2018 due to a reduction in world trade. The OECD estimates German GDP growth of 0.7% in 2019 and 1.2% in 2020. The service sector (including information technology) contributes approximately 71% of total GDP, industry 28% and agriculture 1%. The German economy maintains high budget and trade surpluses, though private investment is relatively low.

The automotive industry in Germany is regarded as one of the most competitive and innovative in the world, and is the fourth largest globally by production. Germany is also a leading exporter of machinery, vehicles, chemicals and household equipment. Germany has the second-lowest seasonally adjusted unemployment rate of all 28 EU member states at 3.0% (Eurostat, 2019). Notably, unemployment barely increased during the financial crisis of 2008, and has fallen significantly since then, in stark contrast to almost all other OECD countries. However, regional disparities remain within the country, especially between the former eastern and western parts of Germany. In 2018, based on the most recent regional assessment, the unemployment rate averaged 7.6% in the east and 5.3% in the west (BMWi, 2018). Since the reunification in 1990, Germany has spent considerable funds to bring eastern productivity and wages up to western standards.

Germany is a federal parliamentary republic with 16 states (*Länder*). There are two representative bodies: a federal parliament (Bundestag) and a federal council (Bundesrat). The members of the Bundestag are elected by popular vote and serve four-year terms (Deutscher Bundestag, 2019). The 69 members of the Bundesrat are not elected, but are based on the composition of the governments of the 16 *Länder*. The head of state is the president, who has primarily representative responsibilities. He or she is elected for a five-year term by the federal convention (*Bundesversammlung*), an institution consisting of the members of the Bundestag and state delegates. The government is led by the chancellor, appointed by the Bundestag. The chancellor appoints federal ministers, including a deputy chancellor. The current government is a coalition of the Christian Democratic Union, the Christian Social Union of Bavaria and the Social Democrats. Though the *Länder* enjoy considerable independence under Germany's federal structure, federal law takes precedence over state laws.

Supply and demand

Despite a recent surge in renewable energy sources, Germany's energy system still depends largely on fossil fuels. Oil and gas are the largest energy sources in total primary energy supply (TPES)[3] and total final consumption (TFC)[4] (Figure 2.2), and coal remains the largest source for power generation. Nevertheless, renewable energy sources, including bioenergy, wind and solar, are making fast progress. Statistically, they have de facto replaced a large share of conventional power in Germany.

Domestic production of oil and natural gas is small, and the country relies on imports. In 2018, total domestic energy production was 112 Mtoe, just over a third of TPES. Coal accounts for the largest share of Germany's energy production, but it is not enough to cover domestic demand, and nearly half of the country's coal supply is imported. Bioenergy and waste account for the second-largest share of domestic production, half of which is used in heat and power generation and the other half in final consumption, either as biofuels in transport (8% of total bioenergy supply), for heating in residential and commercial buildings (28%), or for industry purposes (13%).

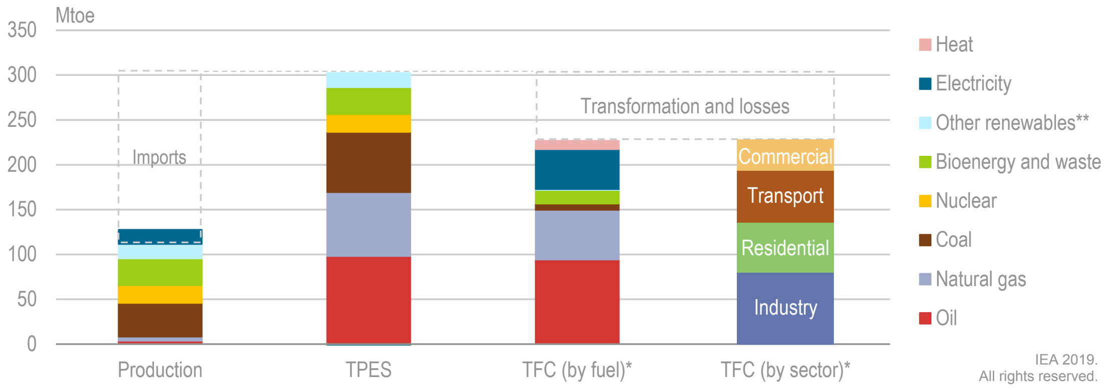
TPES was 298 Mtoe in 2018, with an additional 12 Mtoe of oil products used in international bunkers. Oil, natural gas and coal together accounted for 80% of TPES. While coal, nuclear and most renewable energy sources are used in power generation, oil and gas are used mostly in final consuming sectors. TFC was 227 Mtoe in 2017, of which oil accounted for

[3] TPES comprises production + imports - exports - international marine and aviation bunkers ± stock changes. This equals the total supply of energy that is consumed domestically, either in transformation (e.g. power generation and refining) or in final use.

[4] TFC is the final consumption of energy (electricity, heat and fuels, such as natural gas and oil products) by end users, not including the transformation sector (e.g. power generation and refining).

41%, natural gas for 24% and electricity for 20%. The residential and commercial sectors together consumed 40% of TFC, the industry sector 35% and the transport sector 25%.

Figure 2.2 Overview of the German energy system by fuel and sector, 2018



Germany depends on imports of oil and gas to meet its energy needs; they are the largest energy sources in TPES and TFC across all sectors.

*2017 data.

***Other renewables* includes wind power, geothermal, hydro and solar energy.

Notes: Mtoe = million tonnes of oil equivalent. Supply data for 2018 are provisional. Bunker fuels of around 12 Mtoe are not included in TPES. Electricity exports that accounts for 1.4% of TPES (negative) are not shown in the chart.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Primary energy supply

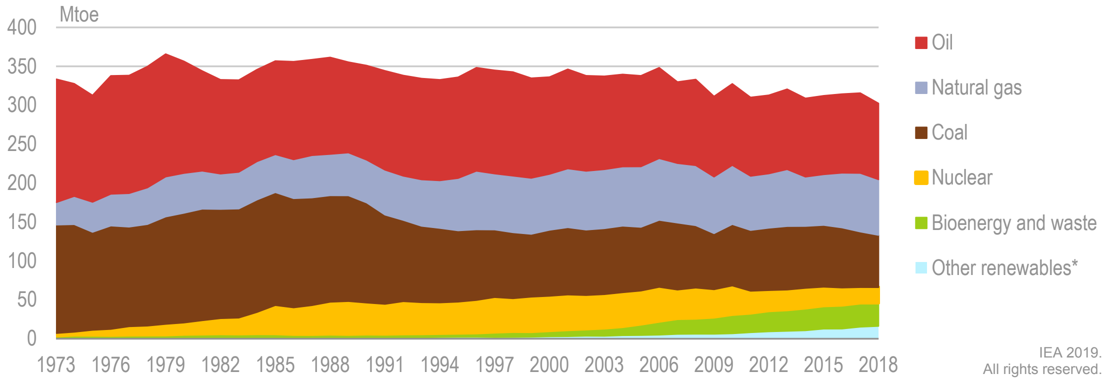
Over the last four decades, Germany's energy supply has shifted from a clear dominance of coal and oil to a more diversified system (Figure 2.3). In 2018, oil accounted for 33% of TPES, natural gas for 24%, coal for 23% and low-carbon energy sources for 22% (while electricity exports deduct 1.4% from TPES). Nuclear energy was introduced in the 1970s and accounted for up to 13% of TPES, but is now being phased out and replaced by other sources.

The trend of more renewables entering the energy system will continue in line with Germany's energy transition targets. Nuclear energy will be completely phased out of the energy mix by 2022 and replaced by more renewables. Furthermore, coal used in electricity generation, which represents around 80% of all coal in TPES, is planned to be phased out by 2038.

The shift from conventional sources to wind and solar power leads to lower thermal losses in the energy transformation, reflected in a decline in TPES in the last decade. This decline has not taken place in final energy consumption.

So far, the growth in renewable energy has mainly replaced nuclear power, another low-carbon energy source. The share of fossil fuels has remained stable at around 80% in the last decade, albeit fell in absolute terms in 2018. Compared with other IEA member countries, Germany's share of fossil fuels is around the median (Figure 2.4).

Figure 2.3 TPES by source, 1973-2018



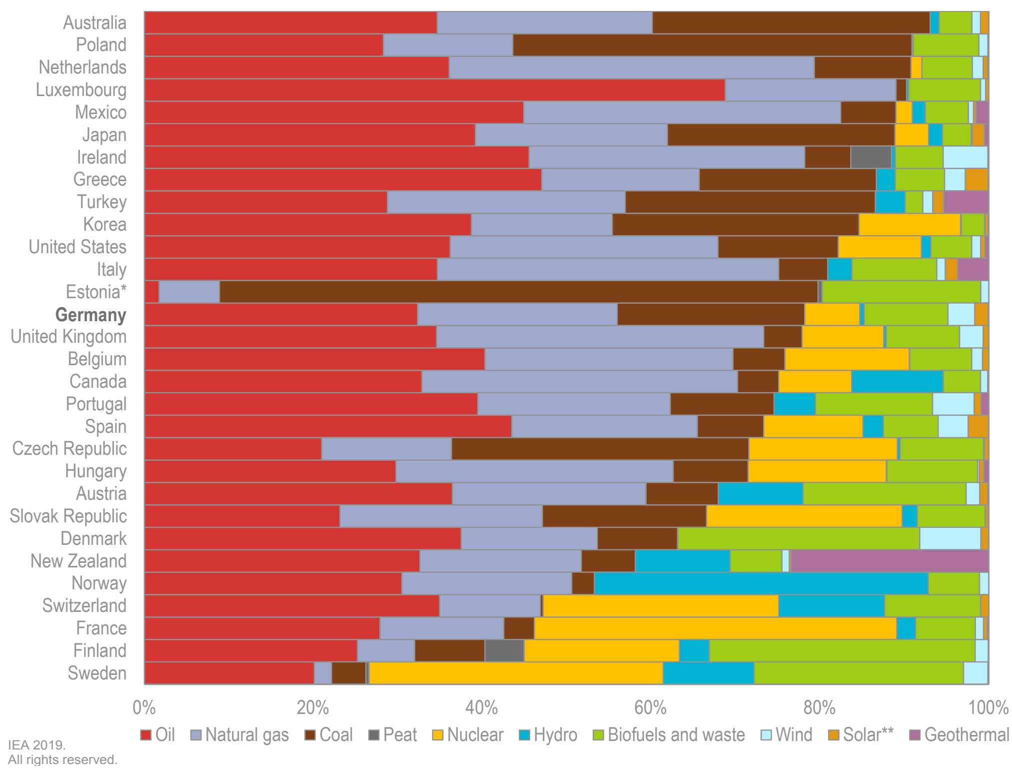
TPES has been relatively stable at around 310 Mtoe in recent years, with growth in renewable energy sources that have mainly replaced nuclear.

**Other renewables* includes electricity from wind, solar, hydro and geothermal.

Notes: Data for 2018 are provisional. TPES does not include bunker fuels. Electricity imports and exports are not shown in the chart.

Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.4 Breakdown of TPES in IEA member countries, 2018



Fossil fuels account for around 80% of TPES in Germany, close to the median among IEA member countries.

*Estonia's coal is represented by oil shale.

***Solar* includes solar photovoltaic (PV), solar thermal, wave and ocean power, and other power generation.

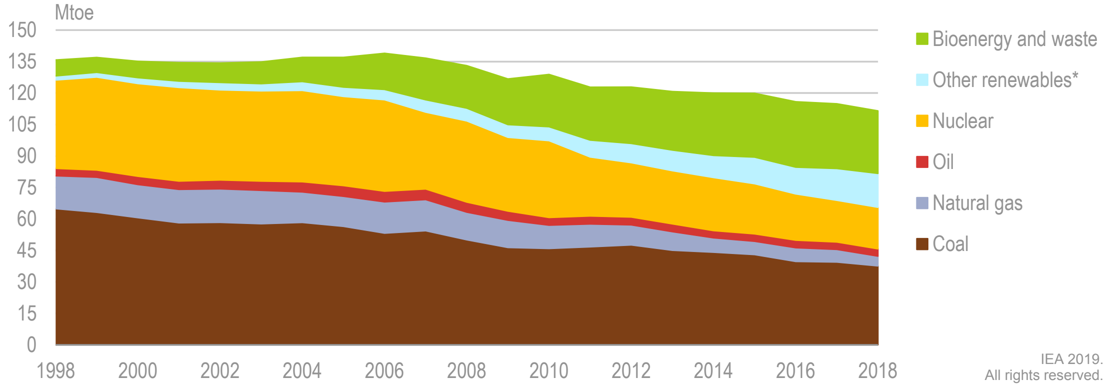
Note: Data are provisional.

Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy production and self-sufficiency

Germany's energy transition is clearly visible in domestic energy production. In the decade from 2008 to 2018, fossil fuel production declined by a third while nuclear production nearly halved. These declines were largely offset by increased production of renewable energy, so total domestic energy production fell by only 16% (Figure 2.5). In 2018, renewables and waste accounted for 41% of total domestic production. The growth in renewable energy production has also helped Germany keep a steady level of energy self-sufficiency of around 40% of TPES (Figure 2.6).

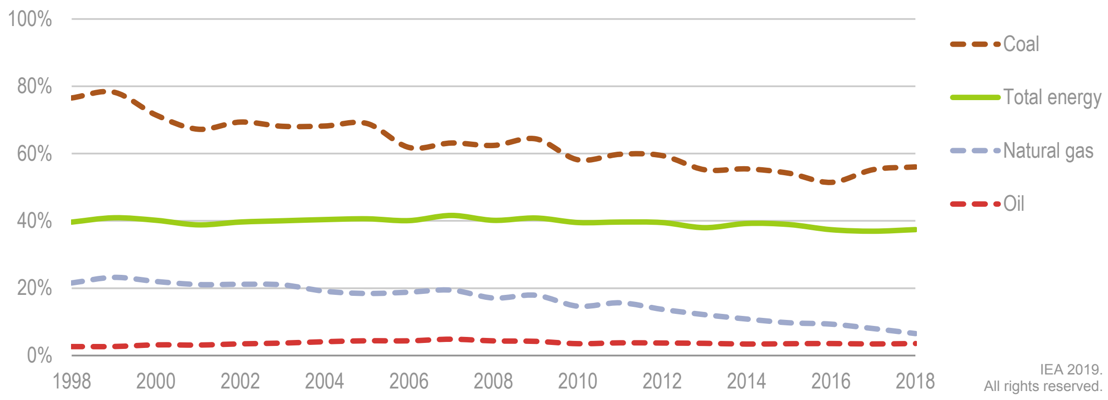
Figure 2.5 Energy production by source, 1998-2018



Renewable energy and waste have increased rapidly in the last decade and accounted for 41% of total energy produced domestically in 2018.

**Other renewables* includes electricity from wind, solar and hydro (and a minor share geothermal).
Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.6 Self-sufficiency (production/TPES) by energy source, 1998-2018



While fossil fuel production is declining, Germany's total rate of self-sufficiency is relatively stable at around 40% of TPES, thanks to the increase in renewable energy production.

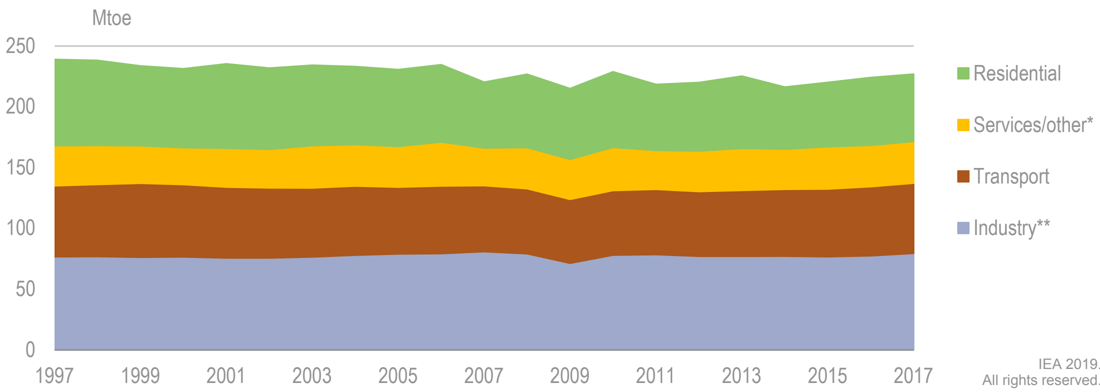
Note: Domestic energy production as share of TPES.
Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Energy consumption

Compared with the decline in TPES and the changing fuel mix, Germany's final energy consumption by sector has remained relatively stable (Figure 2.7). In the last decade, TFC varied between 215 Mtoe and 229 Mtoe, a total difference of just 6%. Most of the variations happened in the residential sector, where heating accounts for the largest share of energy demand and varies with the outdoor temperature. Consumption in the industry sector fell in 2009 after the global financial crisis, but recovered quickly and is back to pre-crisis levels. Transport sector consumption has increased by 8% in the last five years, and is not on track to meet the 2030 target of reducing transport energy demand by 15-20% from 2005 levels.

Fossil fuels accounted for two-thirds of TFC in 2017 (Figure 2.8). The residential and commercial sectors use mostly natural gas and oil for heating purposes and electricity for powering appliances. The industry sector is the single largest energy consumer with over a third of TFC in 2017. This includes fuels used for non-energy purposes, which represent 28% of total industrial consumption, mainly oil and gas in the chemical and petrochemical industry. Transport depends on oil fuels, with only small additions of biofuels, electricity and natural gas. Furthermore, the recent growth in transport energy demand has been met nearly entirely with increased diesel consumption.

Figure 2.7 TFC by sector, 1997-2017



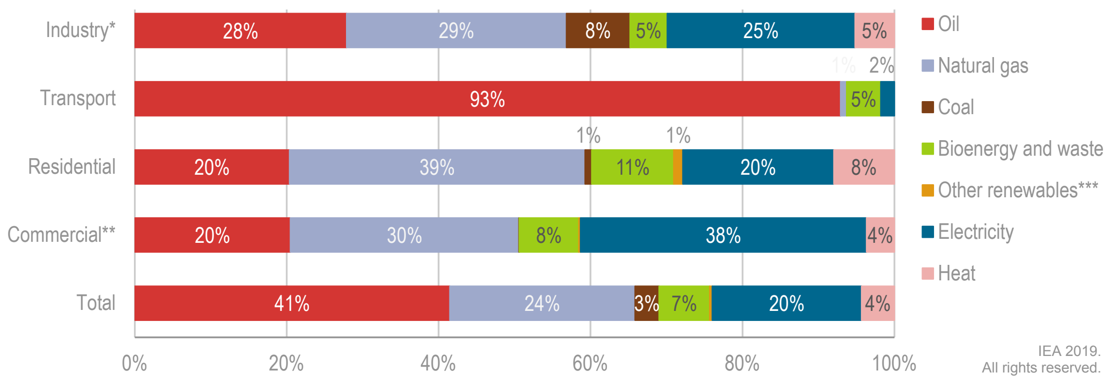
TFC has been relatively stable at around 225 Mtoe for the last two decades, with annual changes in the residential sector due to variations in heating demand.

**Services/other* includes commercial and public services, agriculture, and forestry.

***Industry* includes non-energy consumption.

Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Figure 2.8 TFC by source and sector, 2017



Oil is the largest energy source in TFC, with a dominant position in transport and high shares in industry and buildings; fossil fuels together account for nearly 70% of TFC.

**Industry* includes non-energy consumption.

***Commercial* includes commercial and public services, agriculture, and forestry.

****Other renewables* includes solar heat and a minor share of geothermal.

Source: IEA (2019), *World Energy Balances 2019*, www.iea.org/statistics/.

Institutions

In Germany, the federal government as well as the *Länder* have responsibilities in the field of energy policy. However, the federal government is primarily responsible for establishing legislation on energy policy. The *Länder* contribute to the shaping of energy policy via the federal council (Bundesrat), where they take part in federal legislation.

Germany is a social market economy, and the guiding principle for energy policy is that government interventions are minimised and used only if a market mechanism does not exist or does not work.

The Federal Ministry for Economic Affairs and Energy (BMWi) is responsible for energy policy, the energy transition and climate policy aspects of the energy transition at the federal level. Given that the BMWi is also the ministry that oversees Germany's industries, one of its focus areas is to ensure that the energy transition does not jeopardise the competitiveness of German industry. It is in charge of policy for the market launch of renewable energy, energy efficiency, and emergency planning for oil, gas and electricity. It is also responsible for energy research policy, institutional energy research and project funding for applied energy research. BMWi is the German representative concerning energy policy in the European Union and internationally. Both the BMWi and the Federal Ministry of the Interior, Building and Community (BMI) handle issues related to energy conservation in buildings.

The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) is responsible for environment and climate change policies. The ministry was established in 1986 in response to the Chernobyl nuclear disaster, as a dedicated ministry to address environmental issues. Among its mandates are to protect the public from environmental toxins and radiation, ensure efficient use of raw materials, advance climate action, and promote the use of natural resources to conserve biodiversity and secure habitats

(BMU, 2019a). Beyond crafting legislation within its subject areas, the BMU is also involved in research and development (R&D) efforts to support environmental technologies and in national and international environmental co-operation.

The Federal Ministry of Transport and Digital Infrastructure (BMVI) is responsible for the government's fuel strategy and co-ordination of the energy transition in the transport sector. The BMVI's authority extends across the broad range of transport modes, including aviation, road, rail and water. It also co-ordinates on European transport policy and helps to implement the 2013 Mobility and Fuels Strategy.

In the energy context, the Federal Ministry of Food and Agriculture (BMEL) is mainly responsible for overseeing the bioenergy sector, including biofuels and biomass. In particular, the BMEL promotes the sustainable and environment-friendly production and use of biomass for both domestic fuels as well as imports. The BMEL grants around EUR 50 million for renewable energy R&D with a thematic focus on energy production from biomass. In this regard, it helps implement the 2014 National Policy Strategy on Bioeconomy.

The Federal Ministry of Education and Research (BMBF) is responsible for institutional and project funding in basic applied energy research. Its areas of focus for fostering innovative technologies include energy, climate, health and nutrition, mobility, security and communication. The BMBF works alongside the BMWi and the BMEL to support energy R&D.

The Federal Ministry of Finance (BMF) oversees all aspects of German fiscal and tax policy, including managing the federal budget. In this regard, the ministry is responsible for energy taxation. Fiscal outlays associated with the energy transition, therefore, are conducted in co-ordination with the BMF.

The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur) is an independent federal authority that works in parallel with the BMWi and is authorised to ensure the liberalisation and deregulation of markets in the telecommunications, postal, railway and energy sectors. The Bundesnetzagentur, which is endowed with its own decision-making powers, has the authority to gather information, investigate issues and impose penalties. The authority has regional offices throughout Germany through which it keeps in close contact with consumers and industry. For energy, the regulator has responsibility for grid regulation (third-party access and network charges), systems integration, and network planning and granting of permissions for high-voltage transmission lines. In this capacity, it ensures fair energy prices to consumers, competition in the supply of electricity and natural gas, and approvals for high-voltage transmission lines. Furthermore, Bundesnetzagentur is responsible for the surveillance of wholesale energy trading.

The Federal Cartel Office (Bundeskartellamt) is an independent federal authority assigned to the BMWi whose mandate is to protect competition in Germany. Its tasks include merger control, control of abusive practices of dominant or powerful companies, implementing the ban on cartels, and the review of procedures for the award of public contracts by the federal government. Mergers that are found to have a so-called "community dimension" are examined by the European Commission. Violations of the ban on cartels or abusive practices whose effects are limited to the territory of one state (*Land*) are prosecuted by the competition authority of the respective *Land*. In cases of cross-border dimensions, several national competition authorities within the European Competition Network either co-operate or refer it to the European Commission.

The Federal Office for Economic Affairs and Export Control (BAFA) is also an agency within the BMWi with responsibility to implement export controls, oversee economic development (especially for small and medium-sized enterprises), and to finance measures in the energy sector that promote greater use of renewables and more energy savings.

The Monopolies Commission (Monopolkommission) is a permanent and independent committee of experts that advises the government on issues related to competition. In this regard, it is required by the Law on the Energy Industry to produce a special report every two years on the development of competition in electricity and gas markets.

The German Environment Agency (Umweltbundesamt) was founded in 1974 as Germany's primary environmental protection agency. Its mandates include waste avoidance, climate protection and pesticide approvals. Its work includes gathering data on the state of the environment, investigating interrelationships, making projections and providing other federal bodies, including BMWi, with policy advice (Umweltbundesamt, 2019). The agency also ensures that environmental law is applied in the area of carbon trading.

The Federal Institute for Geosciences and Natural Resources (BGR) is the central geoscientific authority providing advice to the German federal government. It is subordinate to the BMWi. By undertaking its own scientific research and analysis, BGR makes a contribution to enhancing scientific understanding, and thus plays a part in safeguarding Germany's supplies of energy resources. BGR issues a regular report on energy resources in the form of its annually updated energy study Data and Developments Concerning German and Global Energy Supplies.

Energiewende

Germany's energy transition, called the Energiewende, is a major plan for transforming the energy system into a more efficient one supplied mainly by renewable energy sources. In 2010, the federal government adopted the Energy Concept document, which sets out Germany's energy policy until 2050 and specifically lays down measures for the development of renewable energy sources and energy efficiency. In 2011, it was supplemented by the decision to completely phase out nuclear from electricity generation by 2022. As such, the Energiewende is meant to move Germany towards a low-carbon, nuclear-free energy system by the middle of the century.

The energy transition strategy can be summarised by three objectives:

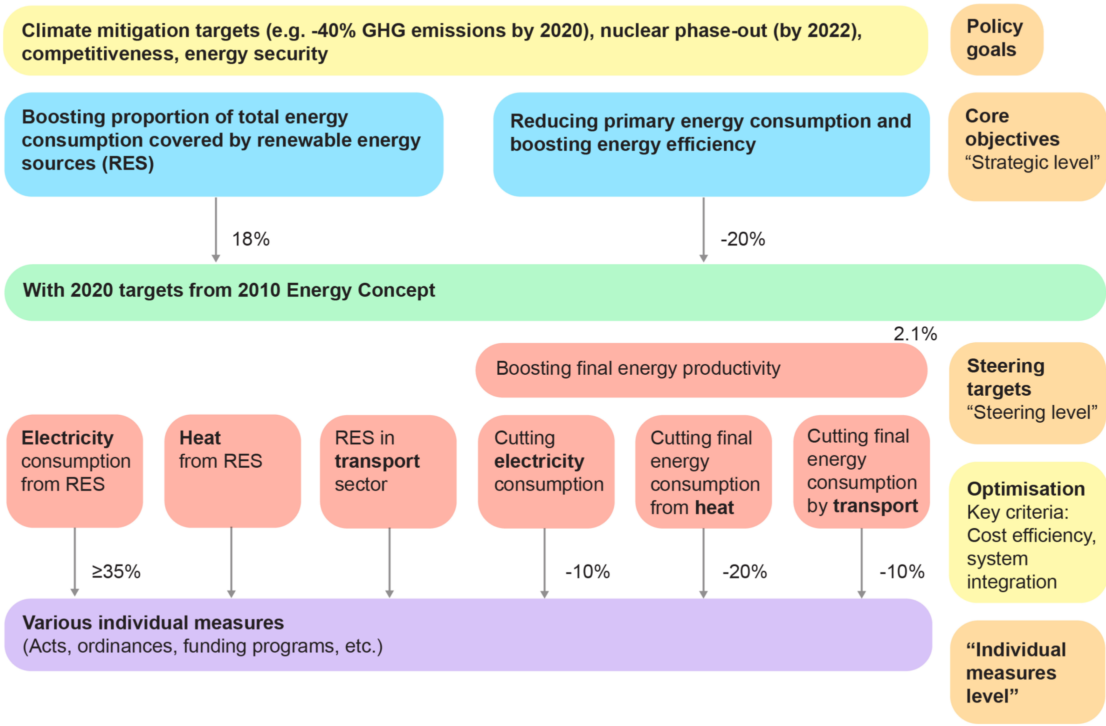
- Reduce energy consumption in all sectors (under the principle of "efficiency first").
- Use renewable energy directly wherever it makes economic and ecological sense.
- Cover the remaining need for energy by renewables-based electricity.

Energy Concept

The German government in 2010 released the Energy Concept to serve as a long-term guiding set of principles to achieve an energy transition by 2050. The Energy Concept, which highlights the triple goals of affordability, energy security and environmental protection, remains Germany's guiding document for realising the Energiewende even today. The document lays out a target to achieve emissions reductions of at least 80%

by 2050 from 1990 levels. In order to achieve this target, the concept focuses on the significant expansion of renewable energy as well as rapid improvements in energy efficiency, establishing sectoral targets up to 2020 (Figure 2.9).

Figure 2.9 Structure and targets of the Energy Concept



Source : Government of Germany.

Specifically, the Energy Concept lays out an objective to cut primary energy consumption by 20% by 2020 and by 50% by 2050 (from a base year of 2008). Additionally, it calls for a reduction in greenhouse gas (GHG) emissions of 40% by 2020, 55% by 2030 and 80-95% by 2050 (from a base year of 1990), as well as growth in the share of electricity consumption from renewable sources to at least 35% in 2020, 50% by 2030, 65% by 2040 and 80% by 2050.

Nuclear phase-out

In 2002, the government decided to phase out the commercial use of nuclear power for electricity generation after existing nuclear power plants reach their legally defined residual electricity production volumes. Following the 2009 parliamentary election, the federal government adopted a modified energy policy that included the idea to use nuclear energy as a "bridging technology" towards more renewable generation. Accordingly, the government extended the operational lifetimes of nuclear power plants by an average of 12 years under the 11th Act Amending the Atomic Energy Act, which entered into force in December 2010.

However, following the Fukushima Daiichi nuclear accident in Japan in March 2011, the German government reassessed the risks associated with nuclear energy and decided to accelerate the phase-out of commercial nuclear power plants through the enactment of the 13th Act Amending the Atomic Energy Act, which entered into force in August 2011. The 13th Act Amending the Atomic Energy Act revoked the additional residual electricity volumes that had been allocated to each operating nuclear power plant in the 11th Act Amending the Atomic Energy Act. In addition, licences for each operating nuclear plant were limited so that all facilities would close by the end of 2022 at the latest. The 16th Act Amending the Atomic Energy Act provides additional rules for an appropriate financial settlement to nuclear plant operators as determined by the Federal Constitutional Court.

Emissions targets

Germany's climate protection policies are embedded in a multitude of national laws and decisions, EU regulations, and international agreements.

Germany's most recent national climate change strategy is defined in the Climate Action Plan 2050, which sets out a longer-term pathway for sector-specific emissions reductions, as reflected in the Energy Concept. Compared with the base year of 1990, the key goals are to achieve a 40% cut in GHG emissions by 2020, 55% by 2030, 70% by 2040, and 80-95% by 2050, at which point the country expects to be mostly GHG-neutral (BMU, 2010). These targets are complemented with short- and medium-term targets for emissions, energy consumption and renewable energy supply.

Because Germany is a member of the European Union, its climate policy is guided by the framework of EU climate policies: the 2020 climate package and the 2030 climate framework. Large combustion facilities in the power and industry sectors are part of the EU Emissions Trading System (ETS), whereas non-ETS emissions until 2020 are subject to the Effort Sharing Decision. The recent Effort Sharing Regulation addresses non-ETS emissions from 2021 to 2030.

To reach the overall GHG emissions reduction target for 2020, the federal government adopted the 2020 Climate Action Programme in December 2014, containing over 110 measures. The key policy strategy areas described in the programme are the National Action Plan on Energy Efficiency (NAPE), a climate-friendly building and housing strategy (Energy Efficiency Strategy for Buildings), transport sector measures (including mileage-based charges for road freight vehicles and federal funds for long-distance public transport), and measures in the electricity sector (to increase renewable energy, modernise fossil fuel power plants and develop more co-generation[5] plants).

Despite progress on lowering overall emissions, Germany is struggling to meet its targets, in large part due to uneven progress across sectors, with notable challenges in transport. According to an external study commissioned by the BMU, Germany would fall 8 percentage points short of its 2020 emissions target, citing economic and population growth as the main drivers. As such, the government aims to achieve as much as possible towards the 2020 target but is now focused on the 2030 goal of cutting emissions by 55% from 1990 levels. Furthermore, in an effort to address transport sector emissions, the government appointed a task force, the National Platform Future of Mobility, to come up with policy recommendations for the sector.

The German government submitted a draft National Energy and Climate Plan to the European Union in December 2018, which highlights five problematic areas for emissions reduction strategies, including energy efficiency and grid extensions (European Commission, 2018).

[5] *Co-generation* refers to the combined production of heat and power.

In order to meet its ambitious GHG emissions reduction target for 2030, the government in March 2019 established a so-called climate cabinet, headed by the chancellor and comprising ministers from relevant ministries, including BMWi and BMU, as well as the transport, interior, agriculture and finance ministries. The cabinet on 20 September released a package of measures (Climate Action Programme 2030) that included a phased carbon pricing system for the buildings and transport sectors, a ban on oil-based heating in buildings from 2026, higher subsidies for electric vehicles (EVs), increased incentives for retrofitting of buildings, and greater public investment in public transport. The climate cabinet proposed lowering the costs for households and companies by providing tax relief and a reduction in taxes and fees on electricity prices (though not a lowering of financial support to renewables). In addition, the proposal includes a process for monitoring and evaluation in all sectors that would require the government to make annual adjustments if emissions reductions are not on track to meet targets. The package was adopted into law by the German parliament in December 2019.

Energy efficiency

Germany has made progress on boosting energy efficiency and decoupling energy demand and economic growth. Still, Germany is not on track to meet its targets from the Energy Concept to cut primary energy consumption by 20% by 2020 compared with a base year 2008.

NAPE, which took effect in 2014, marked an important step towards reducing energy demand. The first area of focus was to provide consumers with information and advice on energy efficiency. The second area of focus was on promoting targeted investment in energy efficiency through incentives. The third focus area was to demand more action, including requiring large companies to conduct energy audits and applying new standards for appliances and newly built buildings.

The government is currently working on a new energy efficiency strategy to cover all sectors. The guiding principle will be "efficiency first". Germany plans to define concrete efficiency measures for 2021-30 to reach the 2030 goals as part of a new National Action Plan on Energy Efficiency 2.0 as well as to comply with the EU Energy Efficiency Directive. Additionally, the government plans to prepare a roadmap to support the national target to halve primary energy consumption by 2050 (compared with 2008). A special focus will be on energy demand in the heating sector and from buildings.

Renewable energy

The 2010 Energy Concept sets out targets for renewable energy in power generation and total energy supply in Germany. By 2020, the target for renewable energy as a share of gross final energy consumption is 18%, consistent with the EU target. Beyond 2020, the German government will seek to increase the share of renewables to 30% by 2030, 45% by 2040 and 60% by 2050. Wind and solar are expected to be the major sources of renewable energy, followed by biomass and hydropower.

For electricity generation, Germany has a target for renewables to account for at least 35% of gross electricity consumption by 2020. In 2018, this share already rose to approximately 38%. The German government has set long-term targets for increasing the share of renewables in electricity to at least 50% by 2030, 65% by 2040 and 80% by 2050. Moreover, the March 2018 coalition agreement states the government's intention to increase the 2030 target to a share of 65% for renewable electricity, contingent on a corresponding expansion in grid capacity. The climate cabinet also reaffirmed the more ambitious target.

The Renewable Energy Sources Act (EEG) is the central instrument for the expansion of renewable energy in the electricity sector. The EEG's first iteration, introduced in April 2000, established guaranteed grid connection and access rights for renewables, priority dispatch, compensation for curtailment, and financial support for 20 years (feed-in tariffs [FiTs] and feed-in premiums) based on project size, technology and location. An EEG surcharge on electricity consumption finances the subsidy for renewables, though energy-intensive industries receive exemptions from the charge to preserve international competitiveness.

As the costs for RES support escalated, reforms in the Renewable Energy Sources Act 2014 introduced market premiums for new RES installations above a minimum threshold and auctions for determining the level of financial support for renewable energy by 2017 at the latest. The first auctions took place in 2015 for ground-mounted PV as a pilot scheme.

The Renewable Energy Sources Act 2017 created a paradigm shift in renewable energy funding towards more competition and generally greater cost efficiency, limiting the previous system of fixed funding rates to smaller installations, which became too costly and less necessary, as the deployment costs of wind and solar came down rapidly. The renewable energy sources with the largest capacity – onshore and offshore wind energy, large PV systems, and biomass – are now required to compete in auctions, where only the cheapest offers are awarded contracts (BMWi, 2019).

System integration of renewable electricity

Germany's Energiewende is clearly visible in electricity generation. Nuclear power has decreased by nearly half in the last decade and been replaced mainly by bioenergy and waste, wind, and solar power. The share of renewables in electricity consumption has steadily grown over the last few years – from around 6% in 2000 to almost 38% in 2018. By 2025, at least 40-45% of electricity consumed in Germany is targeted to come from renewables, according to the EEG.

The German electricity market was fully liberalised in 1998, but additional measures have been enacted since then to adapt to more recent changes to power systems. Most significantly, major market reform occurred with the Act on the Further Development of the Electricity Market, which was adopted in July 2016. The goal of the policy is to make the electricity market suitable to accommodate growing shares of renewable energy and put rules in place for competition between flexible supply, flexible demand and storage. Following a Green Paper and White Paper process, a decision was made to gradually eliminate distortions in the regulatory framework and guarantee competition-based free price formation in a more advanced electricity market, known as the Electricity Market 2.0.

Most wind capacity is located in northern Germany, whereas most demand comes from metropolitan and industrial areas in the south and west of the country. As a result, due to network constraints preventing transmission from the north to the south, northern states are facing power surpluses while southern ones are experiencing deficits, an imbalance that will worsen as the last of the country's commercial nuclear power plants close and offshore wind comes online. The imbalance has resulted in "re-dispatch" measures in the south (where grid operators order power stations to ramp up output to compensate for procured wind power that cannot make it south) and curtailment in the north (where grid operators order wind power to shut down to avoid congestion), costing consumers hundreds of millions of euros annually. The imbalance also creates "loop flows" to neighbouring countries, which have had to invest in grid enforcement and special transformers to maintain security of electricity supply.

Connections to carry wind power from the north to south are insufficient. Public opposition to north-south high-voltage transmission lines has forced costlier underground construction of interconnectors, and public opposition remains an impediment to the siting of necessary infrastructure. Delays to grid expansion experienced thus far have generated significant congestion management costs. As such, grid expansion is a stated priority for the current government to see through the Energiewende.

Coal phase-out

As part of its efforts to halve energy-related carbon emissions by 2030, Germany plans to phase out coal-based power. To reach a broad social consensus on the coal phase-out plan, the federal government established a Commission on Growth, Structural Change and Employment in June 2018. It brought together representatives of environmental associations, scientists, trade unions, economic and energy associations, and representatives from the affected regions. The commission presented its report in January 2019, with a recommendation to completely phase out coal power by 2038. If conditions allow, the phase-out could be brought forward to 2035, an option to be assessed by 2032. As sub-targets, the commission recommended decommissioning 12.5 gigawatts (GW) of coal-fired power plants by 2022 and 25.6 GW by 2030. Furthermore, the commission proposed that coal mining regions, coal miners, ratepayers and coal plant owners receive billions of euros in transitional assistance. The government has accepted the recommendations and is in the process of formulating legislation that reflects the proposals of the commission. In May 2019, the government approved EUR 40 billion in transitional economic assistance to affected regions, per the commission's recommendations (Buck, 2019).

Pricing and taxation

Germany's energy taxation is harmonised with the 2003 EU Energy Taxation Directive, and was implemented into national law with the Energy Duty Act of 2006 and the Electricity Duty Act of 1999. The EU directive lays out minimum excise duty rates on energy products in member countries. Germany has set higher national rates (for example for gasoil/diesel, petrol, liquefied petroleum gas [LPG] and natural gas). The government applies the following tax schemes.

An energy tax is applied on oil products, natural gas, and coal and coke products at rates that vary according to the product's end use in transport or for heating and other applications (OECD, 2018b). The Energy Duty Act provides for several tax concessions, which are based on environmental and economic policy rationale. For example, fuels are not taxed if they are used for electricity generation at power plants with capacities greater than 2 megawatts, or if they meet certain co-generation requirements with heat and power. The government offers tax relief for heating fuels and for electricity used by manufacturing industries and in agriculture, which also receives tax relief on diesel. Natural gas and LPG used as motor fuels also receive tax reductions: for natural gas EUR 13.90 per megawatt-hour (MWh) instead of EUR 31.80/MWh until 2024 (then reduced until 2027) and for LPG EUR 226.06/1 000 kilogrammes (kg) instead of EUR 409/1 000 kg until 2020 (then reduced until 2023). Previous biofuels tax incentives have expired; since January 2015, biofuels are subsidised only through the EU biofuels targets, which value various biofuels categories based on their GHG reduction potential.

Germany also participates in the EU ETS, a cap-and-trade programme that creates a carbon price for obligated participants in the programme, namely power generators, large industrial facilities and airlines for flights within the European Union. Germany has recently adopted a carbon tax for emissions in non-ETS sectors (i.e. buildings and transport), starting with a fixed price of EUR 25/tonne in 2021 and rising to EUR 55 in 2025.

As part of the EEG, a surcharge is added to consumer (industry and household) electricity bills, proportional to their power consumption (as a per kilowatt-hour rate), to pay for subsidies for renewables facilities. Most energy-intensive industries qualify for at least partial exemptions from the charges, pushing a heavier share of costs onto households. The EEG surcharge covers the market premiums and FiTs paid to renewable technologies and the average trading price for electricity. As a result of high FiTs locked in from earlier phases of the EEG, German households pay the third-highest price for electricity among all IEA member countries, at USD 353/MWh in 2018 (IEA, 2019c). Levies, charges and taxes, including the EEG surcharge, accounted for roughly half of the total price; the EEG surcharge amounted to about EUR 81 per household in 2018.

Assessment

The German government has been implementing a set of fundamental reforms to transition its energy systems, referred to as Energiewende. The foundation for these reforms started with the Energy Concept strategy document in 2010. This established a long-term transition plan to source energy mainly from RES.

Germany's reforms have continued at a steady pace since the last IEA in-depth review in 2013, with the adoption of NAPE in 2014 and the Climate Action Plan 2050 in 2016, the passage of Acts on the Further Development of the Electricity Market and on the Digitisation of the Energy Transition in 2016, and revisions to the Renewable Energy Sources Act in 2014 and 2017, among others.

Germany's commitment to its Energiewende reforms is highly commendable. The country has a long-term strategic focus and a tradition of bringing along stakeholders throughout the reform process, and is guided by principles of achieving a triad of energy policy goals of affordability, energy security and environmental protection. This provides a sound basis for Germany to achieve its energy and climate protection goals.

Germany's aspiration to take a leadership position in achieving ambitious climate and energy targets is also highly commendable. By 2030, the German government seeks to reduce GHG emissions by 55% from 1990 levels, increase the share of renewable sources to 30% in gross final energy consumption and 65% in electricity generation, improve final energy productivity by 2.1% per year on 2008 levels, and reduce final energy consumption from transport by 15-20% on 2005 levels.

By 2050, the German government seeks to reduce GHG emissions by 80-95% from 1990 levels, increase the share of renewable sources to 60% in gross final energy consumption and 80% in electricity generation, and reduce primary energy consumption by 50% relative to 2008 levels and final energy consumption from transport by 40% relative to 2005 levels.

Germany has progressed well on its renewable electricity target to date, achieving a nearly 38% share by 2018. Coinciding with planned growth in renewables capacity, the German government has committed to phase out all nuclear electricity generation by 2022. A government-appointed commission also recommended phasing out all coal-fired generation by 2038, at the latest, and the government is working on legislation to incorporate this recommendation into law. The replacement of coal with less carbon-intensive sources will not only help the electricity sector achieve its renewable energy goals but will also contribute to significant emissions reductions to help meet the national target.

However, Germany is lagging behind on its targets for transport (with final energy consumption up by 4.3% in 2017 on 2005 levels) and energy efficiency (with final energy productivity improving at only 1.15% per year). While the share of renewable energy sources is lower than the 2020 target (due to non-electricity sectors), oil remains the main source of Germany's supplied energy, making up a 33% share in 2018. These factors put at risk Germany's ability to meet its near- and longer-term emissions reduction targets; it is projected to underperform against its 2020 target.

Achieving Germany's targets, together with the planned phase-out of nuclear and coal-fired power generation and rapid technological improvements, will result in much more of Germany's domestic generation coming from variable renewable energy, and shifts in Germany's energy consumption patterns.

This requires a significant transformation of Germany's electricity system over the next decade to become much more flexible than it is today. This flexibility can come from network expansion and increased interconnection across Europe, more flexible sources of generation, storage, and demand-side management. In particular, it is well understood that immediate investment in transmission infrastructure is necessary to reduce costs from curtailment and re-dispatch of electricity due to network constraints for Germany's electricity consumers, which increased to around EUR 1.5 billion in 2017.

To successfully deliver on Germany's energy transition, the government will need to accelerate the reform process it has embarked upon. Critically, these reforms will need to extend their focus beyond transitioning the electricity sector to achieve a genuine energy Energiewende as opposed to only a "Stromwende" (electricity transition).

The electricity sector made up only 24% of Germany's final energy consumption (2 542 terawatt-hours) in 2017. The transport sector represented 26%, and heating and cooling represented the remaining 50% share. Success in the electricity sector needs to be replicated in the other energy sectors. Much stronger policy action and relevant market, tariff and taxation reforms will be needed to reduce energy consumption and increase the use of renewables in buildings, industry and transport to achieve Germany's long-term GHG reduction targets.

Failure to accelerate Germany's reforms and achieve a genuine Energiewende will undermine the country's ability to deliver on its ambitious goals and targets. Moreover, its regulatory frameworks may not be able to keep pace with rapidly evolving technologies and business models.

The German government has taken a sectoral approach to meeting its climate and energy targets. The advantage of this approach is that it can allow accountabilities for achieving targets to be assigned to the ministry with responsibility for the sector. However, achieving sectoral targets requires careful co-ordination across policy areas. Policies developed in silos risk omitting important reforms needed in other portfolios in order to facilitate targets being achieved efficiently. Therefore, it is important that relevant experts across policy areas are involved in investigating policy responses needed to address consequences and facilitate the enabling conditions needed for the successful implementation of policy measures.

Without proper co-ordination, policies can result in inefficient and inequitable allocation of the costs of achieving Germany's energy and climate goals. In order to address these challenges, the federal government in March 2019 established a dedicated "climate cabinet" headed by the chancellor, involving all ministers who have responsibilities in the field of climate mitigation. The climate cabinet's proposed package aims to improve Germany's chances of reaching its ambitious climate and energy goals by, among other measures, introducing a carbon price in the transport and buildings sectors as well as boosting incentives for EVs and public transportation. These measures, which were passed into law in December 2019, are a step in the right direction towards ensuring the transition takes place in sectors beyond electricity.

Following an extensive Green Paper and White Paper consultation process, the German government took the decision to gradually eliminate price distortions in the electricity market regulatory framework and strengthen price signals. The passage of Further Development of the Electricity Market act in 2016 established the strict separation of capacity reserves from participation in wholesale markets in order to avoid distorting price signals, only to be used as a backup measure. This was an important reform needed to allow the investments in renewable and flexible sources to be driven by market signals from wholesale prices, the outcome of the renewable energy auctions and the EU ETS carbon price.

However, further distortions to price signals across the energy sector remain, and they are undermining Germany's ability to achieve its energy and climate goals in a cost-effective and equitable way. The burden of taxes and levies is placed disproportionally on electricity consumers, sending signals to consume fuels used in heat and transport that are more emissions-intensive, and undermining the ability for Germany to achieve its sector coupling goals. Moreover, no price signals exist for generators to locate in areas that co-optimise between the availability of resources and network congestion. The amount electricity consumers pay for networks does not vary with use at different times of the day. This can mute signals for consumers to avoid increasing load on the network during peak times. This is particularly important with the planned roll-out of EV charging infrastructure.

There is a perception that households are not able to gain from the benefits of the Energiewende. Concerted effort will need to be made to ensure that reforms that remove distortions of price signals coincide with reforms that give energy consumers the ability to respond, adjust to and benefit from them. The Digitisation of the Energy Transition Act of 2016 is an important step in giving customers more control over when and how they consume electricity. However, progress on smart meter roll-outs has been slow. The German government will also need a detailed understanding of the impacts of removing distortions on vulnerable customer groups. With this understanding, targeted measures can be developed to help them adjust.

Recommendations

The government of Germany should:

- ☐ Expand the scope and ambition of energy and climate policies beyond a focus on the electricity sector, especially to transport and heat, to achieve a genuine energy transition across all sectors.
- ☐ Ensure that when ministries develop energy and climate strategies, in particular sectoral ones, they work closely together to ensure effective co-ordination and that targets and policies are aligned and not working against one another.
- ☐ When designing climate and energy policies, ensure that there is efficient and equitable sharing of effort and benefits across Germany's energy sectors and economic stakeholder groups.
- ☐ Ensure that energy market participants, investors and consumers across the energy system and end-use sectors face price signals that are consistent with Germany's emissions reduction and energy savings targets.
- ☐ Identify vulnerable consumers that are particularly exposed to more cost-reflective price signals and provide support to enable them to adjust, including through targeted energy savings measures, applying revenue-neutral changes to taxes and levies, phasing in reforms over time, and transitional exemptions.

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3. Energy and climate change

Key data

(2017)

GHG emissions without LULUCF*: 906.6 $MtCO_2$-eq, -8.7% since 2005, -27.5% since 1990

GHG emissions with LULUCF*: 891.4 $MtCO_2$-eq, -9.2% since 2005, -26.9% since 1990

Energy-related CO_2 emissions

CO_2 emissions from fuel combustion: 718.8 $MtCO_2$, -8.6% since 2005

CO_2 emissions by fuel: coal 39.6%, oil 34.0%, natural gas 23.7%, other 2.8%

CO_2 emissions by sector: power and heat generation 42.3%, transport 22.7%, industry 13.1%, residential 12.2%, commercial 6.4%, other energy 3.3%

CO_2 intensity per GDP**: 0.20 $kgCO_2$/USD (IEA average 0.23 $kgCO_2$/USD)

*Land use, land-use change and forestry (Source: UNFCCC).

**GDP in 2010 numbers and PPP.

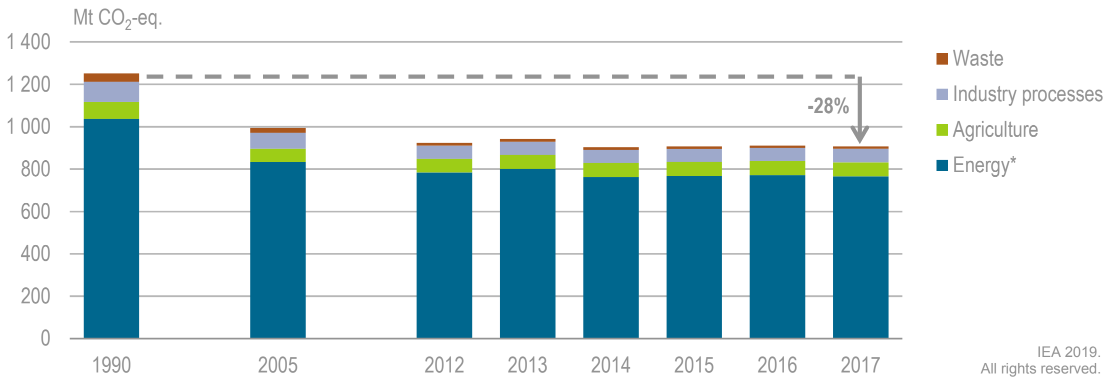
Overview

Germany has set ambitious targets for greenhouse gas (GHG) emissions reduction through its 2010 Energy Concept. The targets are to reduce total emissions by at least 40% by 2020 and at least 55% by 2030, compared with 1990 levels. Despite a rapid increase in renewable electricity generation (38% of gross electricity consumption in 2018), Germany's emissions have not experienced commensurate reductions. As of 2017, Germany had reduced its total GHG emissions by 28% compared with 1990 (Figure 3.1). Still, Germany remains far off its 2020 emissions target. Energy-related emissions, including for power generation, transport, and energy use in buildings and industry, account for over 80% of total GHG emissions.

As a member of the European Union (EU), Germany has national targets for reducing emissions outside of the EU Emissions Trading System (ETS). By 2020, non-ETS emissions are supposed to be reduced by 14% compared with 2005, and by 38% by 2030. Germany is also not on track to meet these targets, with non-ETS emissions (around half of total emissions) in 2017 just 1.5% below 2005 levels (EEA, 2018a).

Germany needs to expand and prepare new policies and measures that can help it reach its national GHG emissions reduction targets in a cost-effective and sustainable way. Notwithstanding the nuclear phase-out, Germany's focus on renewable power and a planned coal phase-out (along with its participation in the EU ETS) will help ensure progress in the power sector. However, additional policies are needed to support emissions reductions outside of the power sector, notably in transport and heating. This can include carbon pricing to create incentives for consumers to choose low-carbon options as well as regulatory options, as explored in this chapter.

Figure 3.1 GHG emissions by sector, 1990-2017



As of 2017, Germany had reduced its total GHG emissions by 28% from 1990, but reductions have stalled in recent years and the level is far from the 2020 target of -40%.

**Energy* includes power and heat generation, commercial, households, industrial energy consumption, and transport.

Note: $MtCO_2$-eq = million tonnes of carbon dioxide equivalent.

Source: UNFCCC (2019), *Germany 2019 National Inventory Report*, https://unfccc.int/documents/194930.

Energy-related CO_2 emissions

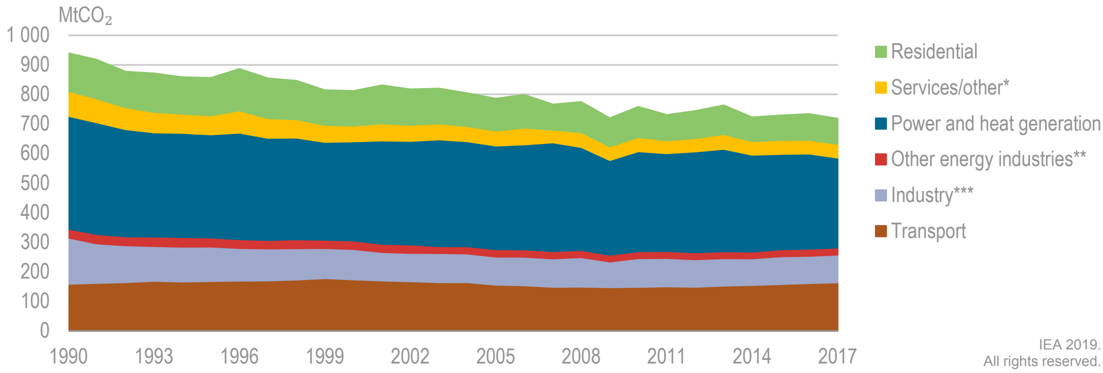
Energy-related carbon dioxide (CO_2) emissions from combustion in power plants, vehicles, industry and buildings account for over 80% of Germany's total GHG emissions, and are the main focus for this chapter.

Energy-related CO_2 emissions have fallen over the last decades (Figure 3.2). In 2017, emissions were 719 $MtCO_2$, 9% below the 2005 value and 24% below 1990. Power and heat generation is the largest source of energy-related CO_2 emissions in Germany. In 2017, the sector accounted for 42% of total emissions, followed by transport (22%), industry (12%), residential (12%), commercial (6%) and other energy industries (3%).

Most sectors have experienced a reduction in emissions in recent years. Residential emissions, in particular, have fallen by 21% since 2005, from energy efficiency improvements and fuel switching, leading to reduced oil consumption for heating. In addition, power and heat generation have experienced significant improvements, with 13% emissions reduction since 2005 (though the nuclear phase-out could have offset some gains in the power sector). The transport sector is the exception to the trend, with a 5% increase in emissions between 2005 and 2017.

The power sector's reliance on coal is reflected in the emissions profile by energy source. In 2017, coal (including blast furnace gas and other recovered gases) accounted for 39% of total power generation in Germany, and about 40% of total energy-related CO_2 emissions (Figure 3.3). Oil accounts for the second-largest share of emissions with a 34% share in 2017, and natural gas for another 24%. Coal emissions have declined in recent years, in line with the fuel shift in the power sector. Oil emissions, on the other hand, have been stable, while reductions in the residential sector have been offset by the increase in transport. Natural gas emissions have increased slightly in recent years, reflecting increased gas consumption in industry and buildings.

Figure 3.2 Energy-related CO_2 emissions by sector, 1990-2017



Energy-related emissions are declining, mainly led by the power sector, whereas transport emissions have increased in the last decade.

**Services/other* includes commercial and public services, agriculture/forestry, and fishing.

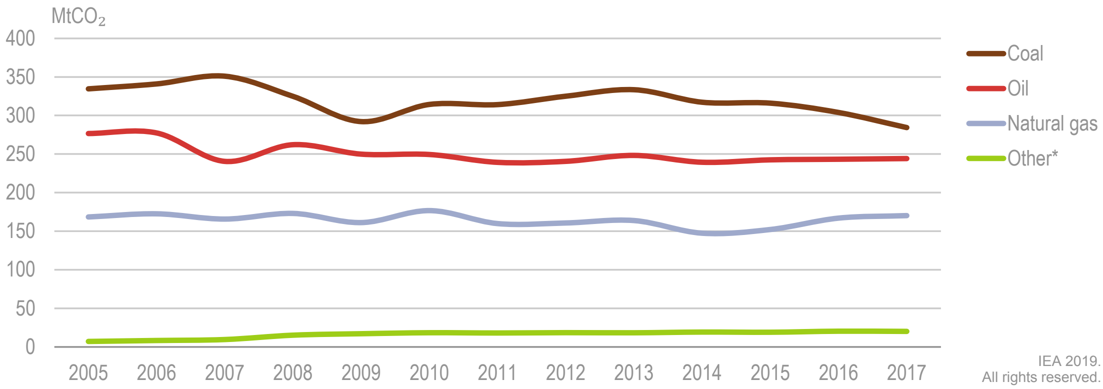
***Other energy energies* includes emissions from coal, oil and gas extraction, oil refineries, blast furnaces, and coke ovens.

****Industry* includes CO_2 emissions from combustion at construction and manufacturing industries.

Note: $MtCO_2$ = million tonnes of carbon dioxide.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 3.3 Energy-related CO_2 emissions by energy source, 2005-17



Coal is the largest source of energy-related emissions, mainly from the power sector; coal emissions have declined with reduced coal power, while oil and gas emissions are stable.

**Other* includes emissions from non-renewable waste.

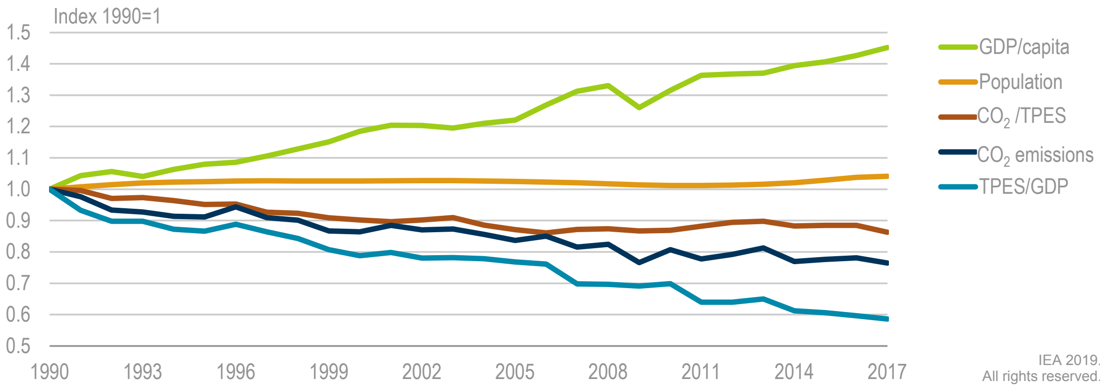
Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

CO_2 drivers and carbon intensity

Total CO_2 emissions in a country are driven by population growth and economic development, along with changes in the energy intensity of the economy (measured as total primary energy supply [TPES] divided by gross domestic product [GDP]) and carbon intensity of the energy supply (CO_2/TPES).

From 1990 to 2017, Germany's GDP per capita grew by 45% and the population increased by 4%, while CO_2 emissions declined by 24% (Figure 3.4). This was mainly achieved through a reduction in the energy intensity of the economy by over 40% (in part due to the reunification of Germany and the shrinking of the former East German economy) as well as a smaller decline in the carbon intensity of energy supply.

Figure 3.4 Energy-related CO_2 emissions and main drivers in Germany, 1990-2017



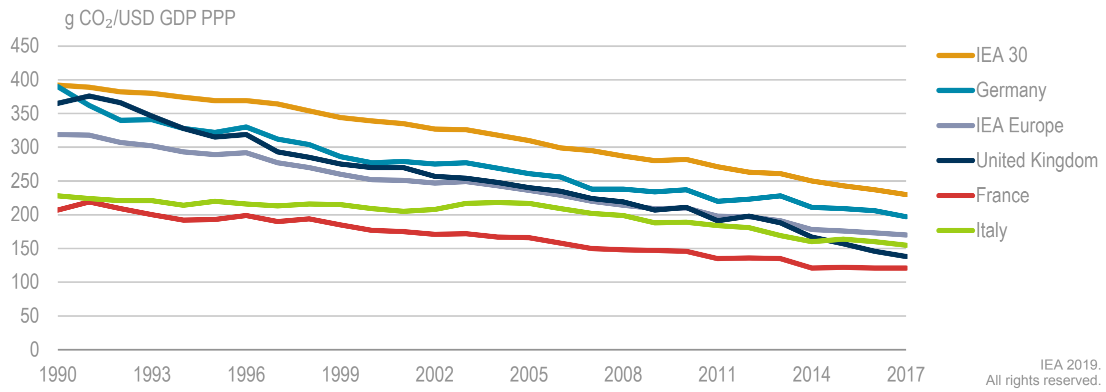
Despite large economic growth per capita, energy-related CO_2 emissions have declined, mostly thanks to the reduced energy intensity of the economy.

Note: Real GDP in USD 2010 prices and purchasing power parity (PPP).
Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Despite the large improvements in CO_2 intensity, Germany had the 10th-highest CO_2 emissions per capita in the International Energy Agency (IEA) and the 12th-highest emissions per GDP (in PPP). In 2017, Germany's CO_2 intensity was 197 kilogrammes of CO_2 per USD (kgCO_2/USD) (PPP), which was 14% below the IEA average but higher than many other European countries (Figure 3.5).

The main explanation for Germany's relatively high CO_2 intensity per GDP is the emissions per kilowatt-hour (kWh) of heat and power. In particular, despite the growth of renewable power, Germany's increasing electricity export surplus and the phase-out of nuclear power limited larger reductions in power sector emissions. In 2017, Germany emitted 390 grammes of CO_2 per kWh (gCO_2/kWh) for electricity and heat, which was above many other European countries as well as the average for IEA countries (Figure 3.6). With continued growth in renewable electricity generation combined with a planned coal phase-out by 2038 at the latest, emissions intensity can decline more rapidly. This is the case for the United Kingdom, for example, where the emissions intensity of heat and power dropped by half in only five years, from 2012 to 2017.

Figure 3.5 CO_2 intensity in Germany and selected IEA member countries, 1990-2017

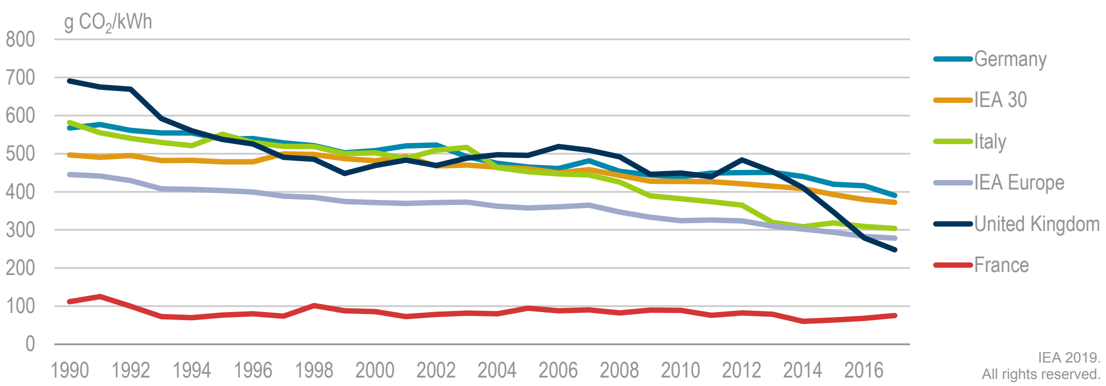


Germany's CO_2 intensity per GDP (PPP) is steadily falling and below the IEA average, but it is higher than many other European countries and the IEA Europe average.

Note: IEA 30 = the 30 member countries of the IEA.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Figure 3.6 CO_2 intensity of power and heat generation in Germany and in other selected IEA member countries, 1990-2017



Germany's relatively high CO_2 intensity is mainly a result of large emissions per kilowatt-hour from power and heat, which are above the IEA average and improving only slowly.

Source: IEA (2019), *CO_2 Emissions from Fuel Combustion 2019*, www.iea.org/statistics/.

Institutions

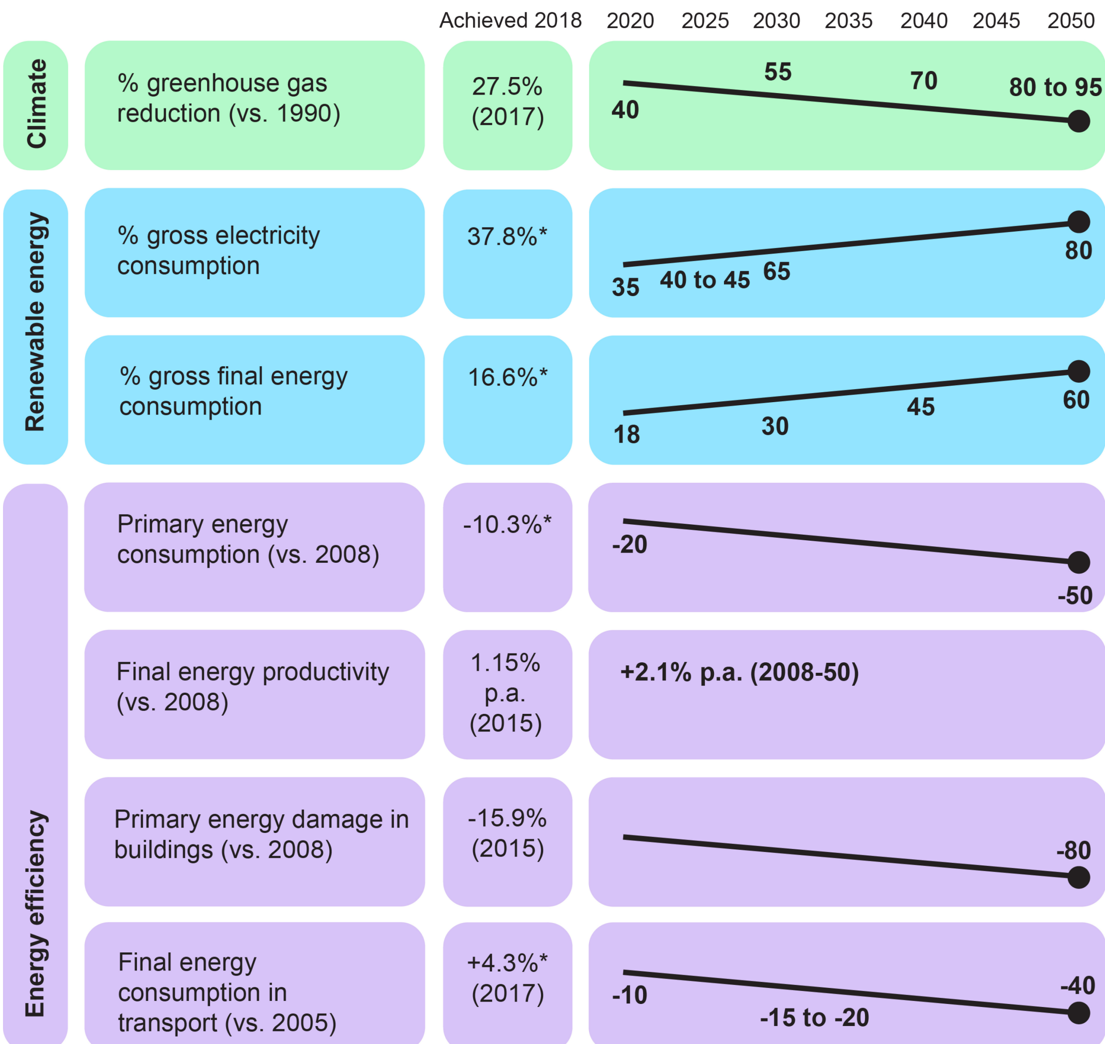
The climate policy aspects of the Energiewende are primarily led by the Federal Ministry for Economic Affairs and Energy (BMWi), including policies that relate to the expansion of renewables and energy efficiency. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) has broad responsibility over managing environmental and climate change policies, including emissions reduction strategies, climate protection and climate adaptation. Both the BMWi and the Federal Ministry of the Interior, Building and Community (BMI) oversee issues related to energy conservation in buildings. The Federal Ministry of Transport and Digital Infrastructure (BMVI) takes the lead on policies governing emissions reduction and fuels strategies for the transport sector.

The Federal Environment Agency (UBA) is Germany's central environmental protection agency. In this capacity, UBA gathers data on the state of the environment, investigates relevant drivers and interrelationships affecting the environment, and issues projections on environmental trends. The German Emissions Trading Authority (DEHSt), which is housed under the UBA, administers Germany's participation in the EU ETS. It also administers emissions trading and licensing of United Nations-led Joint Implementation and Clean Development Mechanism projects.

Emissions reduction targets and policies

Germany's climate protection policies are embedded in a multitude of different national laws and decisions, EU regulations, and international agreements, though there is no national climate change law in place yet.

Figure 3.7 Germany's energy and climate targets



*Preliminary

Note: p.a. = per annum.

Source: Ritter, J. (2019), *Germany's Energy Policy Overview*, BMWi, Berlin.

The Ecological Tax Reform originally introduced taxation on electricity as well as raised taxation on energy products in several steps from 1999 to 2003 to promote ecological behaviour (revenue raised was channelled into the public pension scheme to lower wage-related costs) (IEA, 2012). The 2010 Energy Concept underpinning the Energiewende calls for a reduction in GHG emissions by at least 40% by 2020, 55% by 2030 and 80-95% by 2050 (from a base year of 1990). The targets are subject to annual monitoring; the June 2018 report showed that Germany is not on track to meet its targets.

EU climate framework

As a member of the European Union, Germany's climate policy is guided by the framework of EU climate policies: the 2020 climate package and the 2030 climate framework. Large combustion facilities in the power and industry sectors are part of the EU ETS, whereas non-ETS emissions are subject to the Effort Sharing Decision (ESD). Around half of Germany's GHG emissions fall under the EU ETS system and half under the ESD. As part of the Paris Agreement, the European Union committed to cutting GHG emissions by 40% from 1990 levels by 2030 (Germany, like other EU countries, did not submit a separate Nationally Determined Contribution as part of the Paris Agreement) (BMU, 2019a). In addition, the European Union obliges member states to maintain or improve their anthropogenic climate balance from LULUCF in the period 2021-30 under the so-called LULUCF Regulation.

The EU ETS, which was launched in 2005, requires entities in the power and industrial sectors to participate in a region-wide cap-and-trade programme. Obligated companies can comply by reducing emissions in line with required reductions, buying permits to cover their shortfall or selling permits if they exceed required cuts. As such, the market for permits creates an EU-wide carbon price for the power and industrial sectors that is also relevant for German utilities and industry. Since the launch of the third phase of the ETS (2013-20), the power sector must purchase all its permits at auction, while industry receives 80% of its permits for free. The next phase of the programme (2021-30) will gradually phase out free allocations across sectors. The ETS shifted from national caps during its first two phases toward an EU-wide cap of 25% below 2005 levels by 2020 in Phase 3 and 43% below 2005 levels by 2030 in Phase 4 (European Commission, 2019a). The carbon price as part of the ETS to date has been relatively low due to a surplus of allowances, and therefore insufficient to drive major fuel-switching changes in the power and industry sectors on its own. However, recent changes to the ETS, including the introduction of a Market Stability Reserve for surplus allowances, has bolstered the carbon price; further strengthening of the carbon price will help improve the economic case for the German government's planned coal phase-out.

The ESD requires Germany to reduce its emissions from non-ETS sectors by 14% by 2020, compared with 2005 levels. Germany is not on track to meet this target, with projected non-ETS emissions for 2020 around 11-12% below 2005 levels (EEA, 2018b). In particular, Germany has struggled to achieve emissions reductions in its transportation sector. The European Union has set new targets for non-ETS sectors for 2030, under which Germany is required to reduce its non-ETS emissions by 38% from 2005 by 2030. Failure to meet the targets means that Germany would have to rely on flexibility mechanisms, such as procuring credits from other member countries or international tradeable credits, to cover its shortfall, with the latter option ceasing under the new commitment period starting in 2021 (European Commission, 2019b).

EU member countries are required to submit National Energy and Climate Plans (NECPs) that outline how they plan to meet 2030 targets. The German government submitted a draft NECP to the European Commission in December 2018 that highlights five areas for emissions reduction strategies that remain in flux, including energy efficiency and grid expansions (European Commission, 2018). Moreover, the German government is undertaking its review and acceptance of the recommendations of government-appointed commissions on coal and transport. The government launched an online consultation for the draft NECP between 14 June and 2 August 2019, and plans to submit a final strategy to the European Commission in December 2019 (BMWi, 2019a).

Climate Action Programme 2020

In December 2014, the German cabinet adopted the Climate Action Programme 2020, which outlines measures to be implemented by 2020 to reach the goal set out in the Energy Concept to reduce GHG emissions by at least 40% from 1990 levels by 2020 (BMU, 2018b). The plan contains over 100 implementing measures to help meet the target. Key policy strategy areas described in the programme are: the National Action Plan on Energy Efficiency (NAPE), the Climate-Friendly Building and Housing Strategy, transport sector measures (including mileage-based charges for road freight vehicles and federal funds for long-distance public transport), and measures in the electricity sector (to increase renewable energy, modernise fossil fuel power plants and develop more co-generation[6] plants). The government also launched a process to monitor implementation of the measures and publish an annual climate action report outlining progress on implementation, emissions trends and projected reductions.

Climate Action Plan 2050

The Climate Action Plan 2050, adopted in 2016, reaffirmed the pathway of emissions targets (including interim targets) laid out in the Energy Concept through 2050, with a long-term aspiration to be virtually GHG-neutral by that year (80-95% emissions reduction). The Climate Action Plan 2050 includes 2030 targets for sectors (energy, industry, buildings, transport, agriculture, land use and forestry) based on a linear pathway to achieving the 2050 targets (BMU, 2018a). The plan also lists initial measures for implementation and establishes a process for monitoring and updating policies and measures every five years (in line with monitoring periods under the Paris Agreement). To help achieve the 2030 climate targets in line with the goals of the National Climate Action Plan 2050, the German government plans to legislate a specific programme of measures in 2019 that will also form the building blocks of its NECP to 2030 (see “Climate Action Programme 2030” section below).

Transformation of the energy sector is a critical plank of the Climate Action Plan 2050, including an ambitious buildout of renewable electricity and a phasing out of fossil fuels to cut the energy sector’s emissions by 60-62% by 2030 (from 1990). As part of this effort, it calls for the creation of a government-appointed commission on Growth, Structural Change and Regional Development to arrive at a set of recommendations for managing the structural adjustments to the Energiewende (later known as the Coal Commission [see below]).

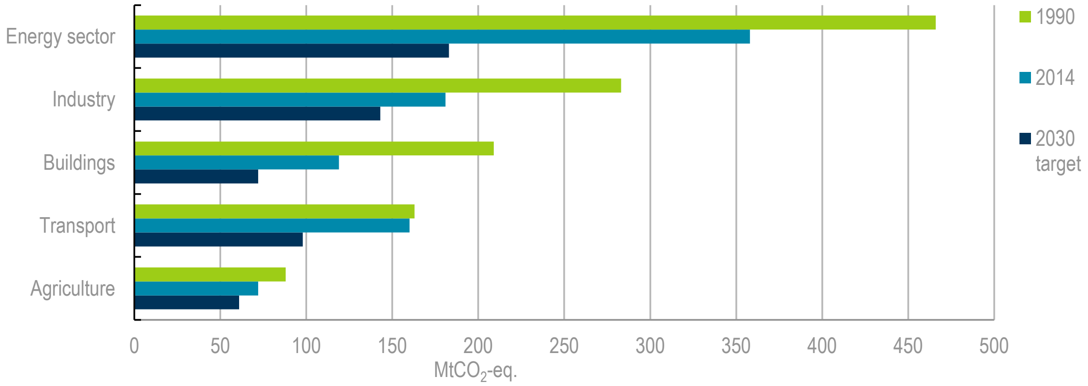
[6] *Co generation* refers to the combined production of heat and power.

For industry, the Climate Action Plan 2050 aims for GHG reductions of 49-51% from 1990 by 2030 through measures such as research and development (R&D) and energy efficiency programmes. The plan targets a reduction of 66-67% by 2030 for the buildings sector, to achieve a "virtually" climate-neutral building stock by 2050, through measures including stringent standards for new buildings, incentives for upgrading the existing building stock and efforts to phase out the use of fossil fuels in heating (BMU, 2019b).

The plan targets transport sector emissions reductions of 40-42% by 2030 and calls for the creation of task forces to make recommendations to the government on measures, including one to meet 2030 targets.

Lastly, agriculture is targeted to reduce emissions by 31-34% by 2030, including by working with the *Länder* to improve fertiliser practices.

Figure 3.8 Sectoral targets in the Climate Action Plan 2050



Source: Reproduced from Ministry for the Environment, Nature Conservation and Nuclear Safety (2017).

Power sector

Germany's Energiewende has borne the greatest results in the power sector, based on a strong policy push to increase the role of renewable power in electricity generation. However, emissions reductions in the power sector have not fully kept pace with the rapid expansion of renewables in a context of increasing electricity exports and the nuclear phase-out, which will be completed by the end of 2022 (see Chapter 11 on nuclear); in addition to renewables, retired nuclear power was substituted by coal- and gas-fired generation. To further reduce power sector emissions, the government is also planning a gradual phase-out of coal-fired generation with a goal to eventually move towards a more efficient and renewables-based power system in order to meet longer-term climate targets.

Renewables

Drastically expanding the role of renewable energy is a central plank of the Energiewende and of achieving Germany's emissions reduction goals, and an area in which the country has made exceptional progress (see Chapter 5 on renewables).

Under the 2010 Energy Concept, renewable energy is supposed to account for 18% of gross final energy consumption by 2020, as required by the European Union. Beyond 2020, the German government will seek to increase the share of renewables to 30% by 2030, 45% by 2040 and 60% by 2050.

Furthermore, Germany aims for renewables to account for 35% of electricity consumption by 2020. Following this, the shares of renewables in electricity are officially targeted to grow to 50-52.5% by 2030, 65% by 2040 and 80% by 2050. According to the March 2018 coalition agreement, the government is planning to speed up growth to 65% renewable electricity by 2030.

The Renewable Energy Sources Act (EEG) is the central instrument for the expansion of renewable energy in the electricity sector. The EEG's first iteration from April 2000 established guaranteed grid connectivity for renewables, preferential dispatch and feed-in tariffs for 20 years, financed by an EEG surcharge on consumers. Reforms to the EEG in 2014 and 2017 shifted the support system from fixed tariffs to competitive auctions, thereby lowering the cost burden of renewables subsidies.

Table 3.1 Germany's climate and energy targets from the Climate Action Plan 2050 and Energy Concept

Target area	2020	2030	2040	2050
GHG emissions, compared with 1990	at least 40%	at least 55%	at least 70%	80-95% (virtually GHG-neutral)
Primary energy consumption compared with 2008	-20%			-50%
Electricity consumption compared with 2008	-10%			-25%
Renewables in gross final energy consumption	18%	30%	45%	60%
Renewables in electricity consumption	35%	50-52.5%*	65%	80%

*The coalition government has set a new target of 65% renewables in electricity generation by 2030.

The results of policy support have been impressive. From 2007 to 2017, the share of renewable energy in Germany's TPES nearly doubled from 7.2% to 13.5%. More significantly, in 2017, renewable energy accounted for 34% of total electricity generation. Despite the strong growth in renewables, however, nuclear closures have shifted reliance to coal- and gas-fired generation, and are therefore offsetting some emissions reductions from renewables.

Coal phase-out

Germany's notable growth in renewable electricity, especially wind power, has not been met with commensurate reductions in GHG emissions, in large part due to the country's continued dependence on coal-fired generation, increasing electricity exports and phase-out of nuclear power. In an effort to address this challenge, the Climate Action Plan 2050 called for the establishment of a Commission on Growth, Structural Change and Employment to form a broad social consensus and make recommendations on structuring the shift away from coal. By the time the commission was established in June 2018, it was dubbed the Coal Commission and focused its efforts on laying out a longer-term plan to phase out coal from Germany's energy mix.

The commission brought together representatives of environmental associations, scientists, trade unions, economic and energy associations, and representatives from the affected regions. It presented its report to the government in January 2019, with a recommendation to completely phase out coal power by 2038 at the latest. If conditions allow, the phase-out could be brought forward to 2035, an option to be assessed by 2032. The phase-out of coal-fired power generation will lead to massive structural changes, especially in lignite regions. The commission adopted a range of measures to ensure that these changes result in sustainable, forward-looking structural development, including EUR 40 billion in transitional assistance to affected regions. The government is in the process of formulating its response to the recommendations and aims to finalise legislation around the coal phase-out in early 2020.

Transportation sector

From a sectoral perspective, transport has been the biggest laggard on emissions reductions and the most significant impediment to Germany meeting its GHG targets. In addition to efficiency improvements in line with EU requirements as well as electric vehicles (EVs), the Climate Action Plan 2050 also identifies alternative fuel engines, local public transport, rail, cycling, walking and digitalisation as playing important roles in achieving climate targets in the transport sector (see Chapter 4 on energy efficiency for more detail on transportation sector policies).

In order to address the lack of progress on transport emissions reduction, the government first launched the National Platform on Electric Mobility (NPE) in 2010 to develop market-based measures that will help transform Germany by 2020 into a leading producer and market for electric mobility systems, including EVs as well as supply chain components and infrastructure. The task force comprised representatives from industry, academia, government, labour unions and civil society. The NPE recommended an approach focused on significantly expanding R&D by the industry, supported by governmental financial assistance, as well as promoting skills training, technology standardisation, and cross-sectoral technological integration (Nationale Plattform Elektromobilitat, 2012). The NPE also recommended complementing these efforts with incentives to encourage consumer uptake of electric cars, including fiscal incentives, low-interest loans, and priority lane and parking access.

More recently, the government in September 2018 replaced the NPE with the National Platform Future of Mobility (NPFM). The goal of the platform is to recommend measures for Germany to meet its target from the Climate Action Plan 2050 of cutting transport emissions by 40-42% by 2030. The NPM is administered out of the BMVI; it is composed of representatives from relevant ministries, states, local government, industry, labour unions and civil society (Nationale Platform Future of Mobility, 2019). Like its predecessor and the Coal Commission, the NPM is meant to develop proposals in an inclusive and consultative manner to ensure broad public support. The platform is meant to consider transport beyond just EVs to include other modes of transportation to create a “largely greenhouse gas-neutral and environmentally friendly transport system that enables efficient, high-quality, flexible, available, safe, resilient and affordable mobility in both passenger and goods transport.” The platform has six working groups:

- transport and climate change
- alternative drive technologies and fuels for sustainable mobility
- digitalisation in the mobility sector
- securing Germany as a place for mobility, production, battery cell production, primary materials and recycling, training, and qualification
- connecting mobility and energy networks, sector integration
- standardisation, certification and accreditation.

The NPM postponed an original deadline to publish findings by the end of 2018 to around spring 2019, though a final report has not yet been published. The climate working group (Working Group 1) published an interim report in March 2019 that outlined a goal of up to 10 million EVs on the roads by 2030 and huge investments in public transport, rail and digitalisation of transport. However, the measures are not expected to add up to achieving the full emissions reductions required under the Climate Action Plan 2050 by 2030. The issues of imposing speed limits, raising fuel taxes and promotion of renewable fuels remain controversial and lacking consensus. However, the interim report did include a recommendation to look into the option of imposing a CO_2 tax on sectors not covered under the EU ETS, a recommendation also made by the climate cabinet and adopted by the government. Despite strong public support for climate action, however, public acceptance of increased fuel taxes remains low.

Moreover, in the past decade, diesel prices have been falling and fuel taxes have stayed steady since 2003. Diesel has lower levels of taxation compared with petrol. As of March 2018, tariffs and value-added tax on diesel were EUR 0.66 compared with EUR 0.87 for petrol (FuelsEurope, 2018).

Box 3.1 Air quality challenges in German cities

Germany's heavy reliance on diesel vehicles in road transport has contributed to lower GHG emissions in the transport sector but rising air pollution, especially nitrogen dioxide (NO2) emissions. An initial assessment published by the Federal Environment Agency in February 2019 found that NO2 levels in 2018 exceeded the EU limit (in place since 2010) of 40 microgrammes per cubic metre in 30 German cities studied, though total NO2 levels fell slightly from the previous year (Xinhua, 2019). Stuttgart recorded the highest concentrations, followed by Munich. Revelations since 2015 of illegal defeat devices being installed in diesel vehicles by German automakers to meet emissions limits have exacerbated concerns about diesel-related pollution.

In response to rising NO2-related air pollution and its associated health implications, several German cities have enacted measures to limit pollution from diesel vehicles, including bans on the use of diesel cars without filters (mostly older cars). Other measures include speed limits and traffic restrictions in certain areas. Moreover, successful lawsuits against local administrations over air pollution are pushing more cities to enact partial bans (including Munich, Stuttgart, Leipzig, Hamburg and Bonn) (Deutsche Welle, 2019). In February 2018, Germany's Federal Administrative Court ruled that municipal bans are legally permitted to address air quality concerns as a last resort and under a phased approach. The European Union has also stepped up pressure on Germany, including a threat to sue, to bring pollution levels down to EU limits.

The German federal government has developed plans and support programmes in response, which include an effort to offer improved service and ticket pricing for public transportation, retrofit or trade-in programmes in cities with high concentrations of pollution, expanded use of digitalisation in local transport systems, and alternative transport options such as EVs and bicycle-sharing schemes. Automakers, for their part, have pursued software updates in newer diesel models that improve efficiency in exhaust systems. Although NO2-related emissions are slowly decreasing, pollution levels continue to exceed EU limits (Umweltbundesamt, 2019a). Efforts to limit air pollution from the transport sector will have co-benefits for CO2 reduction as well.

Energy efficiency

In the Energy Concept from 2010, Germany set the target of cutting primary energy consumption by 20% by 2020 and by 50% by 2050, compared with base year 2008 (see Chapter 4 on energy efficiency).

As Germany is making progress on decarbonising electricity supply, decarbonisation of heat supply in buildings is becoming a more important focus area. In line with its overall efficiency targets, the federal government has set a goal to achieve a virtually climate-neutral building stock by 2050. In order to reach the long-term goal, a wide range of measures has been implemented, including financial incentives for investments, energy research initiatives, and consultation and information to consumers.

One of the main sources for financing energy efficiency measures and programmes in Germany is the Energy and Climate Fund, established by federal law in 2010 and financed with revenues from permit auctions under the EU ETS (BMWi, 2019b). Programmes range from direct financial support to information, communication measures and advisory services. In 2018, auction revenues directed EUR 2.6 billion into the fund, in addition to EUR 2.8 billion of federal budget funds that were also allocated to the fund.

While reducing total primary energy consumption by more than 10% since 2008, Germany is not on track to meeting its ambitious 2020 efficiency targets. As such, the government has adopted an “efficiency first” approach to emissions reduction that will emphasise the role that energy efficiency can play in achieving GHG targets. To this end, the government plans a cross-sectoral Energy Efficiency Strategy as well as NAPE 2.0 that will outline specific efficiency measures that the government will pursue over the period 2021-30. The release of the plan will be co-ordinated with finalisation of the NECP and a planned climate bill (see below).

Climate Action Programme 2030

The German government aims to aggregate a first programme of measures, including those that reflect the work of the coal and mobility commissions. As part of this effort, and to elevate the issue of climate change on the policy-making agenda, the government in March 2019 formed a so-called climate cabinet. The cabinet, which is headed by the chancellor, includes representatives from the ministries of economic affairs and energy, environment, transport, finance, and agriculture; the environment minister serves as the deputy chair of the group. The cabinet on 20 September released the Climate Action Programme 2030, a package of measures that comprised climate legislation that was passed into law in December 2019.

The climate policy package targets a reduction in the energy sector’s carbon emissions to 175 million tonnes (Mt) to 183 Mt by 2030. For the electricity sector, it recommends a 65% target for renewables by 2030 (as adopted by the coalition agreement). To this end, it proposes extending the solar support scheme by abolishing the current capacity cap of 52 gigawatts (GW), raising the target for offshore wind capacity to 20 GW, and imposing a 1 000-metre minimum distance between onshore wind installations and residences to address social acceptance.

One of the key measures in the package is the introduction of a carbon price in the non-ETS sectors of transport and heating in 2021. The initial proposal included a price that would be fixed at EUR 10 per tonne of CO_2 in 2021 without a quantitative limit on emissions, increasing by EUR 5 annually to EUR 35 in 2025. Based on an agreement between the government and states in December 2019, the final package raised the fixed price to EUR 25 in 2021, increasing to EUR 55 in 2025. After 2026, the system would introduce a gradually falling emissions cap, which would reduce the maximum amount of certificates available, allowing the programme to set the carbon price. In keeping with the principle of budget neutrality, revenue from the carbon price will be used to compensate consumers via reductions in electricity prices.

In addition, the package supports the coal phase-out recommended by the Coal Commission and calls for a ban on oil-based heating in buildings from 2026, higher subsidies for EVs, increased incentives for retrofitting of buildings, greater public investment in public transport and the promotion of rail over airlines. The proposal includes a process for monitoring and evaluation in all sectors that would require the government to make annual adjustments if emissions reductions are not on track to meet targets. The package still requires federal cabinet approval, followed by passage in the Bundestag and the Bundesrat, planned before the end of the year.

The package will also inform Germany's final NECP, which was due to be submitted to the European Commission by the end of 2019.

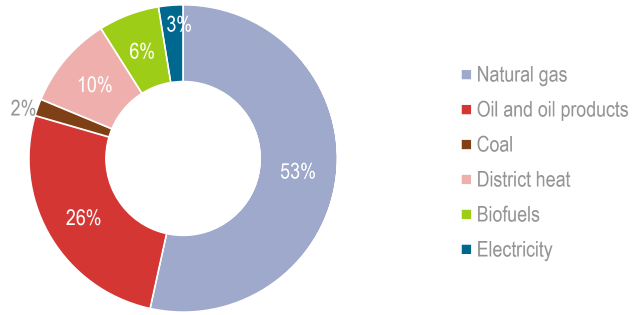
Focus area: Decarbonising heat and sector coupling

Despite Germany's progress to date on decarbonising the electricity sector, as well as a longer-term plan to further achieve emissions reductions in the power sector, the government recognises that more progress is needed in other sectors, notably in heating and transport, in order to achieve the overall carbon reduction targets defined in the Climate Action Plan 2050. The mobility commission was set up to help devise a plan for decarbonising the transport sector, while heating – which accounts for over 50% of final energy consumption and around 40% of emissions – remains a sector in which the government is still in the process of formulating a plan for decarbonisation.

According to BMWi, around 10 million heating systems (mainly residential and commercial) throughout the country are over 15 years old and are often highly inefficient. Roughly 25% of heating systems are still based on oil (though no new buildings are fitted with oil boilers, so as the building stock is rebuilt over time, the use of oil boilers will decline). Moreover, a number of households (especially in remote, rural areas) are not linked to the gas grid or to district heating systems. In contrast, just 2% of buildings use heat pumps, though their installation is rising in new buildings. Overall, Germany's heating sector is highly dependent on fossil fuels, accounting for 81% of direct heat supply in residential space heating in 2016 (Figure 3.9). Furthermore, a large share of district heating and electricity is produced from fossil energy sources, which makes the share of renewable energy in residential space heating less than 10%.

Natural gas is the largest energy source in the residential and commercial sectors (where over 80% of energy consumption is for space and water heating), accounting for 36% of total consumption, followed by electricity at 27% and oil at 21%. Direct use of biomass for heating has increased by 60% in a decade, and accounts for about 10% of total energy use in residential and commercial buildings. The share of district heating has fallen in the last decade to 6% of residential and commercial consumption in 2017.

Figure 3.9 Energy supply in residential space heating in Germany, 2016



Source: IEA (2018), *Energy Efficiency Indicators 2018*, www.iea.org/statistics/.

Along with increasing efficiency, using more renewable energy in heating systems will form a critical plank of decarbonising Germany's heating sector (also see Chapter 4 on energy efficiency and Chapter 5 on renewables). Renewable energy in heating can be supplied directly or indirectly. Direct use includes solar heating, biomass, geothermal heat or biogas (fed into gas networks). Indirect use refers to district heating or electric heating, produced from renewable sources.

Given Germany's heavy dependence on fossil fuels for heating, along with its rapid growth in renewable electricity, there is an attractive opportunity to both increase the direct role of renewables in heat generation and pursue sector coupling, to use more renewables-based electricity for heating. Electric heating can be supplied locally by heat pumps in buildings or through large-scale power to heat production in district heating systems. Large-scale electrification of heating can pose challenges to the electricity grid by shifting energy demand to the power sector, but through sector coupling it can also bring opportunities for improving efficiency in the energy system overall.

However, high electricity costs, driven by levies, charges and taxes (including the EEG surcharge to subsidise renewables) are impeding opportunities to use more electricity in the heating sector, especially in a context of low taxation on fossil fuels (also see Chapter 5 on renewables and Chapter 7 on electricity).

The government intends to include a plan to decarbonise heating as part of the NAPE 2.0. According to the draft NECP, the share of renewable heat needs to double from 14% to 27% by 2030. Moreover, the Climate Action Programme 2030 included several notable measures to decarbonise the heating sector, including a CO_2 price and a ban on the use of oil-based boilers from 2026.

Incentives for energy efficiency and renewable heat in buildings

Broadly speaking, Germany's dual strategy for decarbonising the heating sector is to maximise energy efficiency gains while simultaneously increasing the role of renewables. The government roughly targets cutting energy consumption in buildings by half and increasing the share of renewables to 60-70% of consumption by 2030.

Standards are used to a greater extent for new buildings, including a minimum statutory level for renewable energy in new buildings. Specifically, from 1 January 2016, new buildings are required to achieve a reduction of around 25% in primary energy consumption and around 20% in heat transfer losses (BMWi, 2015). Despite the government's notable policies on improving efficiency in new buildings (see Chapter 4 on energy efficiency), however, the still sizeable existing building stock means that renovation will need to become a stronger focus in order to meet overall decarbonisation goals.

The Heating Cost Ordinance, originally passed in 1989 and last updated in 2009, introduced consumption-based billing for heat and hot water to encourage consumers (usually building owners) to reduce their level of consumption.

The government also uses colour-coded efficiency labels as part of the EU Energy Labelling Regulation on heating systems and boilers. Since January 2016, Germany has used an updated efficiency label on boilers of more than 15 years in age, along with information on advisory and funding services available to switch to more efficient systems (ZVSHK, 2019). The government also offers "energy checks", including "heating checks", in which energy efficiency consultants visit homes to provide recommendations on using energy more efficiently (BMWi, 2019d). However, households have generally shown reluctance to upgrade their heating systems.

Financial incentives are the primary instruments that Germany employs to help improve efficiency and increase the role of renewables in the heating sector. The government launched the Energy Efficiency and Heat from Renewables Support Strategy over 2017-20 to restructure various support programmes to target audiences on a thematic basis more specifically. The focus areas include: 1) energy-efficient buildings, 2) energy efficiency in industry and commerce, 3) heating infrastructure, and 4) saving electricity in private households. As part of this effort, the government has created a one-stop shop for information on the programmes to potential beneficiaries.

The Renewable Energies Heat Act (EEWärmeG) took effect in 2009, with a goal to raise the share of renewable energy in heating and cooling to 14% by 2020, a goal it is already close to meeting. It included a provision that a specified level of heating for new buildings be supplied by renewable energy. The government's 2015 progress report on the act indicated that it has been effective at driving renewables growth in the heating sector.

The Energy Conservation Act (EnEG) and the Energy Saving Ordinance (EnEV) outline energy efficiency requirements for new buildings. The government plans to merge the regulations included in the EEWärmeG, EnEG and EnEV into a planned new Act on Energy in Buildings to consolidate and streamline compliance requirements for energy performance in new buildings.

The government runs the CO_2 Building Renovation Programme, which provides financial incentives for energy-efficient renovations, such as low-interest loans and repayment and investment grants, through the state-owned promotional bank, KfW. In order to qualify for funding, homeowners and other facilities need to demonstrate that they exceed legal energy efficiency requirements as set out in the EnEV. The programme's 2017 budget was EUR 2 billion, the bulk of which was used for low-interest loans; around 400 000 households received funding in 2017. Under the programme, KfW covers up to 30% of the cost of renovations; greater energy savings from refurbishment qualify for higher levels of funding. BMWi estimates that one out of three retrofits of homes benefits from KfW funding (BMWi, 2019e). For the time being, Germany does not provide financial incentives in the form of tax breaks to households or businesses for energy efficiency renovations, though such incentives are included in the proposed Climate Action Programme 2030.

The Market Incentive Programme (MAP) provides funding, in the form of investment or repayment grants to supplement low-interest loans, towards investments in renewable heating and cooling installations, including solar thermal, heat pumps, geothermal and biomass installations. The MAP receives over EUR 320 million in funding annually, mostly focused on existing buildings. For smaller installations, such as households, the Federal Office for Economic Affairs and Export Control (BAFA) offers investment grants. For larger facilities, as well as for heat networks and storage, KfW offers low-interest loans and repayment grants.

The government also introduced the Energy Efficiency Incentive Programme (APEE) in January 2016, which provides additional financial incentives for efficient ventilation and heating installations. Specifically with respect to heating, the programme provides incentives to replace inefficient oil and gas heating systems with more efficient ones. The programme funds upgrades from older oil and gas boilers to new heating systems, both fossil fuel- and renewables-based, which could to some extent lock in fossil fuel consumption (and associated emissions) in the sector for longer periods. Fossil fuel heating systems are funded through grants or loans under the KfW Energy-Efficient Modernisation programme while renewables heating systems are funded through the MAP. In August 2016, APEE was extended to include innovative fuel cell heating systems.

Lastly, the government in 2016 introduced the Heating Optimisation Programme, a promotion scheme to subsidise up to 30% of the costs of exchanging heat pumps and hiring experts to optimise heating systems' functionality to further boost efficiency.

Taxation

The government provides tax relief for heating fuels used by the manufacturing, agriculture and forestry sectors to protect against international competitiveness concerns, including where tax regulations are not harmonised yet across the European Union. Specifically, the Energy Tax Act provides for full tax exemption on heating fuels used in energy-intensive processes by industry.

Co-generation facilities, such as district heating plants, also receive preferential tax treatment. Facilities that co-generate heat and power in non-mobile plants with a monthly or annual capacity utilisation of at least 70% are fully exempt from the energy tax on fuel inputs.

As mentioned previously, an EEG surcharge is added to consumer (industry and household) electricity bills in proportion to their power consumption to pay for subsidies to renewables facilities. However, most energy-intensive industries qualify for at least partial exemptions from charges, levies and the electricity tax, pushing a heavier share of costs onto households. The EEG surcharge in 2018 was 6.79 euro cents per kilowatt-hour (c/kWh) (or 23% of the electricity price), and has ranged between 6.2 c/kWh and 6.9 c/kWh since 2014 (BMWi, 2019c). As such, German consumers (especially households) pay among the highest electricity rates among IEA countries. The renewables support policy, along with ETS prices, means that the financial burden for overall CO_2 reduction is significantly higher on electricity consumption than on other energy modalities. Given the lack of additional taxes on heating fuels for instance, the disproportionate surcharges on electricity deter switching from fossil fuel-based heating systems to heat pumps using electricity (which is increasingly derived from renewables).

Table 3.2 Energy tax rates for heating fuels

Fuel	Energy tax
Light fuel oil	
Sulphur content of more than 50 milligrammes per kilogramme (mg/kg)	EUR 76.35/1 000 litres
Sulphur content of a maximum of 50 mg/kg	EUR 61.3/1 000 litres
Heavy fuel oil	EUR 25.00/1 000 litres
Liquefied gas	EUR 60.60/1 000 kilogrammes
Natural gas	EUR 5.50/megawatt-hour

Source: Germany questionnaire submission to IEA.

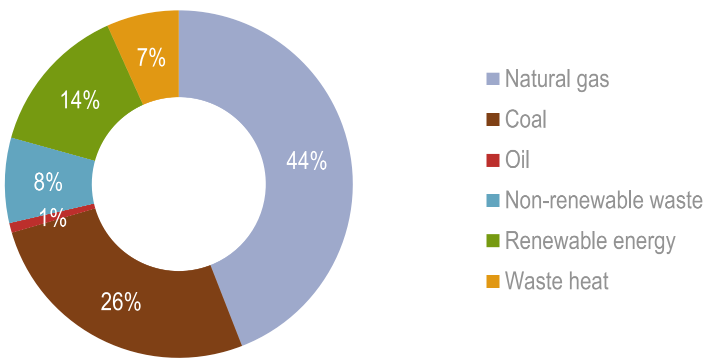
District heating

The use of district heating in Germany is relatively minor compared with several other European countries. As such, district heating covers a small but important share of residential heat demand in Germany and is becoming more important in urban areas. For example, district heating supplies over 20% of heat demand in recently constructed apartment buildings. In 2017, total district heating production was 140 terawatt-hours (TWh) and the net consumption of district heat (after losses) was 124 TWh. The Co-generation Support Act established a target to achieve 110 TWh of electricity generation from co-generation by 2020 and 120 TWh by 2025 (compared with 96 TWh in 2016, when the act was signed).

There are several projects in service in Germany, operated mainly by municipal utilities, which provide heat to urban areas. Municipal utilities usually own the co-generation facilities and may also procure heat from nearby power or industrial plants. In addition, private operators as well as industrial parks also provide local heating services.

Fossil fuels dominate Germany's district heating production. In 2017, natural gas accounted for 44% of total production, coal 26% and oil 1%. Non-renewable waste accounted for another 8%. Renewable energy accounted for 14%, mainly biofuels and renewable waste and a small share of solar thermal and geothermal heat. The remaining 7% of district heating is supplied with industrial waste heat.

Figure 3.10 District heating sales by fuel used for generation, 2017



Source: Reproduced from Germany questionnaire submission to IEA.

District heating systems are usually operated by municipal utilities. The district heating market is unregulated and the supplier sets the price. However, companies are required to provide information on how prices are set, including the share of fuel costs in price changes. Customers are generally allowed to switch from district heating to other heat supplies (in-home heat pumps, natural gas/oil boilers, etc.), but would need to have the resources and authority to retrofit their accommodation. The *Länder* can authorise municipalities to impose a mandatory connection to district heating for certain areas and customers. Around 35% of district heating sales have at least a partial obligation to use district heating. Many municipal-owned district heating networks do not allow third-party access.

More than two-thirds of district heat is produced in co-generation plants, which also provide just under 20% of Germany's total electricity generation. Since 2002, the Combined Heat and Power Act provides support for co-generation through a bonus payment on sold electricity (though the subsidy is more pertinent for industrial co-generation rather than district heating). The act was revised in 2016, with funding extended up to 2022. Revisions also included targeted support to gas-fired co-generation facilities to reduce emissions as well as focused funding on boosting flexibility to accommodate rising shares of renewables on power grids.

Since 2017, support for co-generation plants with capacities of 1 megawatt (MW) to 50 MW has been determined by auction (in a similar manner to the support for renewables). The government has a target to increase the share of co-generation in total power generation to 25% by 2020.

Supporting a larger role for renewables in district heating networks necessitates lowering the operating temperature of networks, which are currently running at high temperatures (100°C to 120°C). As such, the shift to renewables will need to be complemented by strong improvements in energy efficiency, including insulation measures.

Germany also supports investments in modern district heating systems. In 2017, the government introduced the Heating Network Systems 4.0 programme, which provides investment grants for heating infrastructure with low temperatures (20°C to 95°C) and high shares of renewable energy and waste heat. The programme is currently scheduled to run until 2021, but is expected to continue beyond that date. Funding is provided for feasibility studies (up to 60% of the cost) and for the realisation of a fourth-generation heating networks system (up to 50% of the project costs).

Heating systems naturally have a storage capacity, as once a space is brought to the desired temperature, it can retain this temperature even if the heating system is turned off for short periods of time. This is especially true for buildings that are well insulated. If there is effective coupling between electricity generation and heat production, this inherent heat storage capacity could be used to support integration of variable renewables (for example, in response to a sudden drop in solar photovoltaic output, an electrified heat system could quickly reduce its heat production to prevent the need for an increase in generation from natural gas plants). This natural storage capacity of heating systems can be augmented with additional heat storage, especially for district heating and co-generation systems, which have the capacity to heat and store large quantities of water. In a coupled heat and electricity system, this increased heat storage can further assist with incorporating variable renewables, which in turn would further aid decarbonisation.

Adapting to climate change

Germany has already started to feel the effects of climate change in the form of extreme weather events, including a heat wave in 2018 that highlighted the negative impacts on the agricultural sector from climate change. The average temperature in Germany in 2017, at 9.6°C, was one of the eighth-warmest years since the start of weather reporting in 1881. Sea levels around Germany have gone up by 10 centimetres to 20 centimetres in the past 100 years. In the past 50 years, the government estimates that extreme weather events such as heat waves and heavy rainfall are becoming more frequent and more severe (BMU, 2016). The German Weather Service foresees drier year-round conditions in eastern Germany, higher risk of heatwaves in eastern Germany and the Rhine Valley, increased risk of river flooding in the North German lowlands, and higher flooding risk in southern Germany due to heavy rainfall.

As a result, health challenges for the population are expected to increase, as will risks to water management systems and transport infrastructure systems. Weather changes will also have an affect on biodiversity, including by increasing the presence of invasive species and introducing risks from new diseases. Drought conditions are likely to affect crops and yields in the agriculture and forestry sectors (though benefits could emerge from longer growing seasons for certain crops such as soybeans). Droughts will also affect the shipment of goods when water levels in rivers are low as well as the ability to use water to cool thermal power plants.

In order to manage the impacts of climate change, Germany has adopted an institutional and methodological framework for dealing with climate change adaptation. This includes scientific research programmes, participation and consultation processes, and ongoing reporting systems.

In 2008, the federal government passed the German Climate Change Adaptation Strategy (DAS), which outlines targets and options for adaptation strategies. The strategy holds that adapting to the effects of climate change in the energy industry is primarily the responsibility of the industry, with governments at the federal and state levels playing a supportive role (KliVO, 2019).

In 2009, the government established the Interministerial Working Group on Adaptation to Climate Change and the Federal/*Länder* Working Group on Adaptation to the Impacts of Climate Change. Nearly all federal ministries are represented in the Inter-ministerial Working Group on Adaptation to Climate Change, led by the BMU. Monitoring reports are supposed to be released every four years, vulnerability assessments every six years, and Adaptation Actions Plans and Progress Reports every four years. The first evaluation report of the adaptation process is planned for 2019.

The Adaptation Action Plan from 2011 (APA I) included concrete measures to meet the DAS adaptation goals for all levels of society, from citizens to local, national and international governments (BMU, 2011). It was developed in close co-ordination with the states, municipalities, academia and civil society.

The government released the First Progress Report on the DAS in 2015, which indicated that climate adaptation had become more systematically considered in planning, especially in areas such as agriculture, urban planning and cross-sectoral projects. At this time, the government also released a second Adaptation Action Plan (APA II) and agreed to 140 of the DAS' binding measures on adaptation. The APA II outlined six clusters of activities: 1) water, 2) infrastructure, 3) land, 4) health, 5) economy, and 6) special planning and civil protection (Umweltbundesamt, 2019b). The next progress report is under way and will be released in 2020, together with the third Adaptation Action Plan (APA III).

For the energy industry, the APA includes a focus area within the infrastructure cluster, which covers electricity, transport and production. The 2015 Progress Report estimated overall limited vulnerabilities, but also projected notable changes to the sector, especially in the areas of heating and cooling demand, cooling water for thermal power plants, and disruptions to power plants and energy production facilities (BMU, 2016). The APA II notes a priority focus on power plants to avoid cooling water shortages and damage to generation facilities.

However, other areas of energy supply can also be impacted by climate change. Notably, in 2018, historically low water levels in the Rhine River disrupted the supply of petroleum products by barge, sending fuel prices up. Future heatwaves could result in a recurrence of low water levels that create more challenges for fuel supplies.

Assessment

As a member of the European Union, Germany's climate policy is guided by the framework of EU climate policies and the national Climate Action Plan. For example, large combustion facilities in the power and industry sectors are part of the EU ETS, whereas non-ETS emissions are subject to the ESD until 2020 and, subsequently, to the Effort Sharing Regulation (ESR). Around half of Germany's GHG emissions fall under the EU ETS system and half under the ESD.

Germany has a comprehensive set of GHG emissions reduction targets over different time frames: 2020, 2030, 2040 and 2050. Only the 2030 targets are broken down at the sectoral level. Germany's long-term climate target under its Climate Action Plan 2050 is to cut GHG emissions by 80-95% (to achieve "virtual" GHG neutrality) by 2050. The implications of this range diverge substantially in terms of technologies that would be required to achieve the targets. For example, for passenger cars, whereas battery EVs are expected to contribute substantially to an 80% target in 2050, additional hydrogen infrastructure may be required for achieving a 95% target.

Germany's national GHG emissions reduction targets for 2020 and 2030 are equally ambitious. The government is aiming to achieve GHG emissions reductions of at least 40% from 1990 levels by 2020 and of at least 55% from 1990 levels by 2030. GHG emissions were 28% lower in 2017 compared with 1990 and emissions have been rising since 2014. As a consequence, the national target for 2020 is at risk. There may be a need to use potentially costly alternative compliance options to achieve the 2020 target for sectors not covered by the EU ETS, where Germany is required to cut emissions by 14% compared with 2005.

The latest projections indicate not only a gap to 2020 targets, but also a significant gap to the 2030 national target under the ESR of a 38% reduction (compared with 2005) for non-ETS sectors. While several policy options are already identified in view of the 2030 targets, additional policies and measures underpinning the 2030 targets have been discussed and formulated by a number of advisory bodies to the government, involving a wide range of stakeholders. These include, among others, the NPM (for transport policies) and the Commission on Growth, Structural Change and Employment (for the coal phase-out). While the stakeholder approach helps ensure broad consensus on the policy pathway forward, the sectoral segmentation of strategies also risks application of divergent assumptions, goals and scenarios in the development of strategies.

A climate cabinet of ministers, led by the chancellor, was set up in March 2019 to co-ordinate sectoral policies to reach overall energy and climate goals, including to decide on concrete measures and to accelerate the implementation process of policies. Elevation of the climate agenda to the highest levels of government demonstrates strong commitment to meeting the climate targets. Moreover, the policy actions reflected in the Climate Action Programme 2030 will help non-electricity sectors shoulder some of the costs of the Energiewende.

In terms of energy-related emissions, the deployment of renewable electricity contributed to emissions reductions in the 2020 time frame. Energy efficiency in buildings has also improved substantially since 2005, leading to a drop in emissions from the buildings sector. The government's focus on meeting future targets remains centred on renewables and energy efficiency. Looking ahead, there are also plans to phase out all coal-fired generation and increase the share of renewable electricity to 65% (by 2030), highlighting the strong role that renewables will continue to play in meeting Germany's climate targets. The government is currently in the process of considering the recommendation of the Commission on Growth, Structural Change and Employment to phase out all coal by 2038 at the latest and pass legislation on the plan by the end of 2019.

Still, in order to meet the ambitious climate targets, more emissions reductions are needed from sectors beyond electricity. Transport emissions, in particular, have bucked an EU-wide trend and increased since 2005. Both in view of the 2030 targets and for longer-term decarbonisation in line with the Climate Action Plan 2050, continuous emissions reductions will be required in the transport and buildings sectors, considering their sizeable shares in total energy consumption. In line with these goals, planning policies and measures in the transport and building sectors that are sufficient for target achievement in 2030 could send a strong signal to the private sector, including for supportive infrastructure. To this end, the recommendations in the Climate Action Programme 2030, as approved by the government, are a step in the right direction.

Sector coupling holds strong potential for achieving mid- and long-term decarbonisation objectives. Beyond the sectors covered by the EU ETS, more consistent price incentives driving decarbonisation and avoiding lock-in effects should be considered as a means for flexible and cost-effective target achievement, including carbon pricing and fuels taxation. Without such a revised incentive system, sector coupling options to attain GHG reduction targets will lack commercial incentives. It is also essential that changes to pricing systems take into account distributional effects; reforms could start on the basis of a review of the Ecological Tax Reform Act of 1999.

Due consideration should be given to the co-benefits of carbon pricing for reducing air pollutant emissions and improving air quality and public health. Germany is not meeting air quality standards in several cities. In that context, it is noted that Germany still maintains a lower tax rate on diesel over petrol, a tax distortion that several other European countries have started to address in order to attain air quality standards.

Low taxation, or implicit subsidies, countering decarbonisation objectives, such as for heating oil, are ineffective. Related investments in oil heating boilers could be locked in over a period of up to 30 years, and such subsidies should be phased out as a matter of priority in view of Germany's long-term decarbonisation objectives. Moreover, on a 2050 perspective, clearer roadmaps could be identified for process-related emissions in industry, for instance by using carbon capture and utilisation.

In the context of sector coupling, the government should pay attention to the implications of energy consumption shifting between ETS and non-ETS sectors. Allocation of revenues from auctions under the EU ETS for the Energy and Climate Fund is positive.

On adaptation, while an assessment of 2015 considered the risks of climate impacts for energy security as low, recent extreme weather events have led to limitations in inland waterway transport leading to more limited oil supply and to limitations for the operation of thermal power plants (coal supply and cooling). Attention should be paid to events with impacts on energy security in the ongoing evaluation of the adaptation process for 2019.

Germany has set up a comprehensive monitoring framework for tracking progress towards its 2020 and 2050 targets. The government can expand upon progress in this area and use a comprehensive evidence base of ex post evaluations for readjusting policy instruments more systemically in view of reducing gaps towards targets or developing additional policies and measures.

Recommendations

The government of Germany should:

- Prepare policies and measures that are sufficient to attain national GHG emissions reduction targets and remove barriers for the effectiveness of these additional policies and measures.
- In the context of an overall review of price incentives (prices, taxes, levies) in all energy sectors (electricity, heating and cooling, transport), consider carbon pricing in sectors not covered by the EU ETS while taking into account distributional consequences and realistic time frames for phasing in these price signals supporting the energy transition.
- Concretely embed sector coupling in all energy and climate policies, including through enhanced co-operation within the federal administration and with regional administrations.
- Make more systematic use of ex post evaluation results in order to improve the effectiveness of existing policies and measures.

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4. Energy efficiency

Key data

(2017)

TFC: 227.0 Mtoe (oil 41.5%, natural gas 24.4%, electricity 19.7%, bioenergy and waste 6.7%, coal 3.2%, district heat 4.3%, solar 0.3%), +3.0% since 2007

Consumption by sector: industry 35.0%, transport 25.4%, residential 24.5%, commercial 15.2%

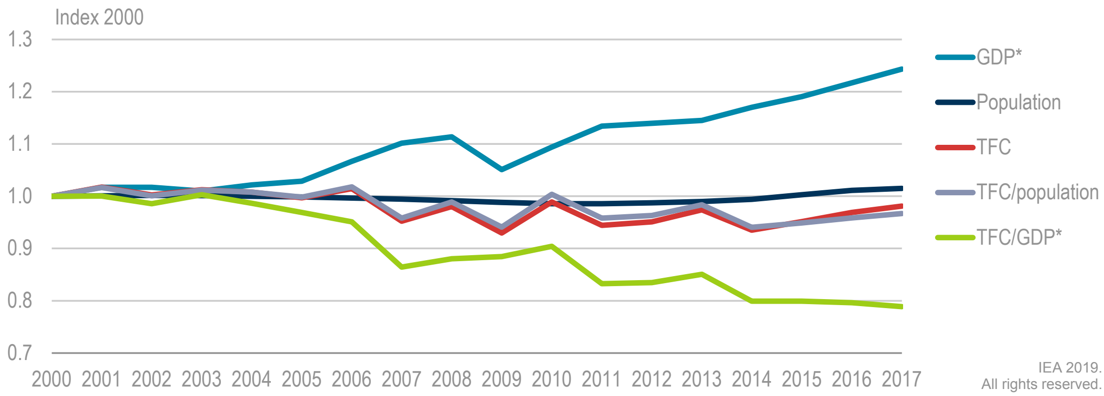
Energy consumption (TFC) per capita: 2.7 toe (IEA average 2.9 toe)

Energy intensity (TFC/GDP): 62.3 toe/USD million PPP (IEA average: 73.9 toe/USD million PPP), -9% since 2007

Overview

Germany's energy intensity has declined over recent decades, supported by its efforts to integrate its energy efficiency strategy with its climate strategy. Despite the steady increase in gross domestic product (GDP) between 2000 and 2017, total final consumption (TFC) was relatively stable, showing a decoupling of economic growth and energy consumption (Figure 4.1). Meanwhile, TFC per capita has also remained stable.

Figure 4.1 Energy supply and drivers, 2000-17



Germany's total energy consumption has remained stable despite continued economic growth, demonstrating improved energy efficiency and lower energy intensity of the economy.

* GDP data are in USD billion 2010 prices and purchasing power parity (PPP).

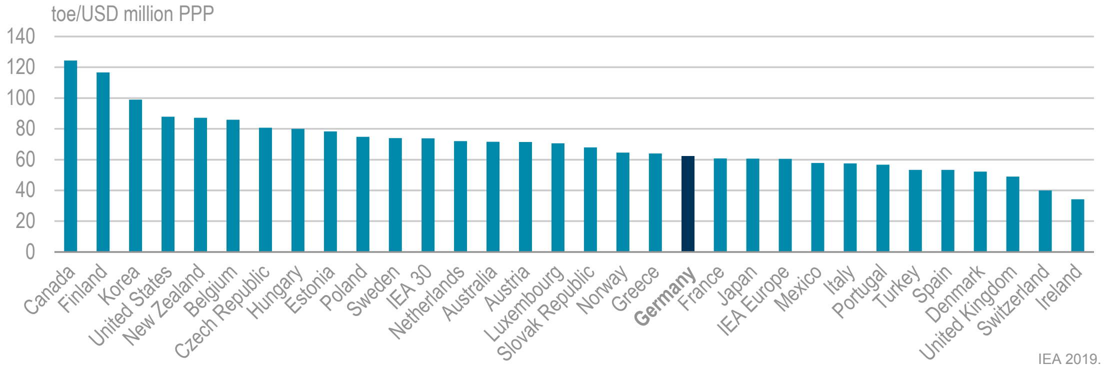
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Reflecting the declining trend in energy intensity over the past decade, Germany ranked 19th in 2017 among International Energy Agency (IEA) member countries in terms of TFC per GDP, about 19% lower than the IEA average. However, per capita energy consumption in Germany was only 5% lower compared with the IEA average, and above the median among IEA countries (Figure 4.2).

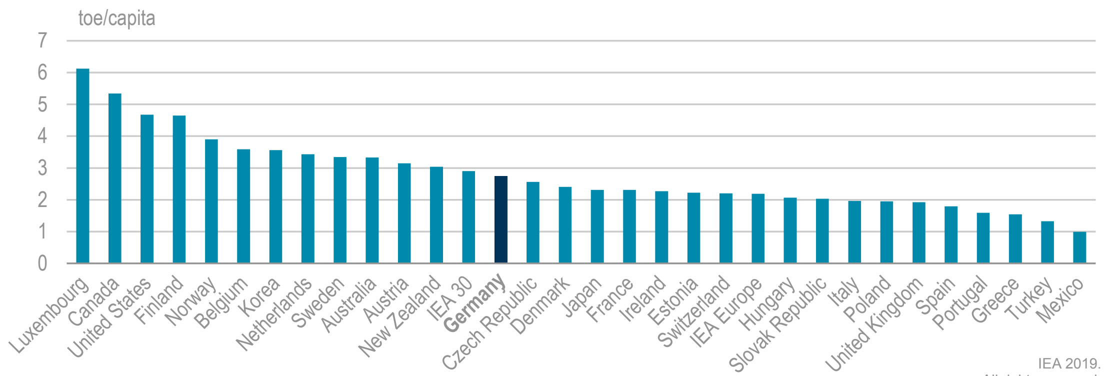
While reducing total primary energy consumption by more than 10% since 2008 in 2018, Germany is not on track to meet its energy efficiency targets set out in the 2010 Energy Concept: to reduce primary energy consumption by 20% by 2020 and 50% by 2050, both compared with 2008. The government needs to make further progress by developing more specific energy efficiency policies and regulatory frameworks for all sectors.

Figure 4.2 Energy intensity in IEA member countries, 2017

Energy consumption per GDP (TFC/GDP PPP)



Energy consumption per capita (TFC/capita)



Germany's energy consumption per GDP is below the median in an IEA comparison, while consumption per capita is slightly above the median.

Notes: IEA 30 = 30 member countries of the IEA; toe = tonnes of oil equivalent. Energy intensity in total final energy consumption, not including the energy transformation sector. GDP data are in USD billion 2010 prices and PPP.

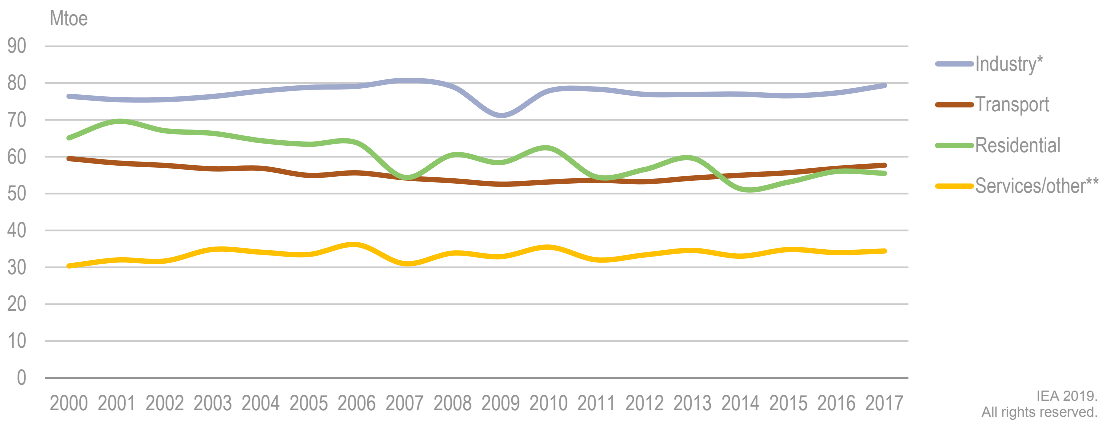
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Energy consumption by sector

Germany's energy consumption has been relatively stable in the last decades. In 2017, TFC was 227 million tonnes of oil equivalent (Mtoe), 2% below the level in 2000, but 3% higher than in 2007. TFC dropped sharply in 2009 due to a decline in energy demand in the industry sector after the 2008 financial crisis, but recovered quickly to pre-crisis levels.

The industry sector is the largest energy consumer in Germany, with 35% of TFC in 2017 (Figure 4.3). The residential sector used to be the second-largest consumer in the country but was surpassed by the transport sector in 2014. In 2017, transport accounted for 25% of TFC and the residential sector for 24%. The commercial sector accounts for the lowest share of TFC at 15%. However, if looking at the residential and commercial sectors together as representing buildings, they account for the largest share of energy consumption in Germany.

Figure 4.3 Final energy consumption by sector, 2000-17



TFC is relatively stable for most sectors, with the exceptions of a drop in industry consumption after the financial crisis and fluctuating energy demand in buildings.

*Includes non-energy use.

**Includes commercial and public services, agriculture, forestry, and fishing.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

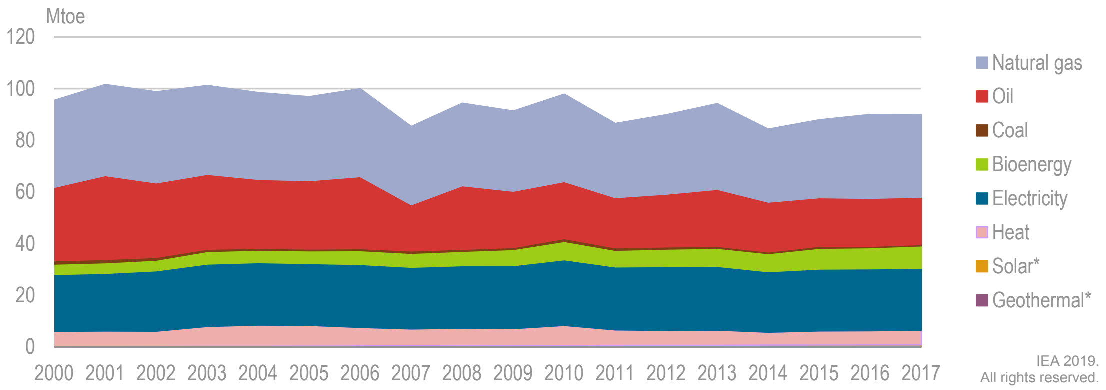
Residential and commercial

The residential and commercial sectors together consumed 90 Mtoe in 2017, accounting for 40% of TFC in the country. This is mainly energy consumption in buildings, largely for heating, which fluctuates annually with outdoor temperatures (Figure 4.4). However, the long-term trend is towards lower energy demand, as buildings get more energy efficient (though renovations of the relatively old building stock will be a critical component of achieving additional improvements). The trend is especially clear in the residential sector, where the average energy demand over the five-year period 2013-17 was 6% below the previous five-year average. The commercial sector increased its average energy consumption by 2% over the same five-year comparison, as a result of a growing service sector in the country.

Natural gas is the largest energy source in the residential and commercial sectors, accounting for 36% of total consumption, followed by electricity at 27% and oil at 21% (Figure 4.4). Direct use of biomass for heating has increased by 60% in a decade, and accounts for about 10% of total energy use in residential and commercial buildings. The share of district heating has decreased in the last decade to 6% of residential and commercial consumption in 2017.

Similar to other European countries, more than 80% of energy consumption in residential buildings is used for space and water heating (Figure 4.5). The rest is mainly electric appliances and small shares for cooking and lighting. Natural gas is the main source for space and water heating, supplying around half the energy consumed. The rest is supplied by oil, biomass and district heat. The energy intensity of residential space heating per floor area decreased by 7% between 2010 and 2016 (IEA, 2018), indicating energy efficiency improvements from higher standards in new buildings and renovations.

Figure 4.4 TFC in residential and commercial sectors by source, 2000-17



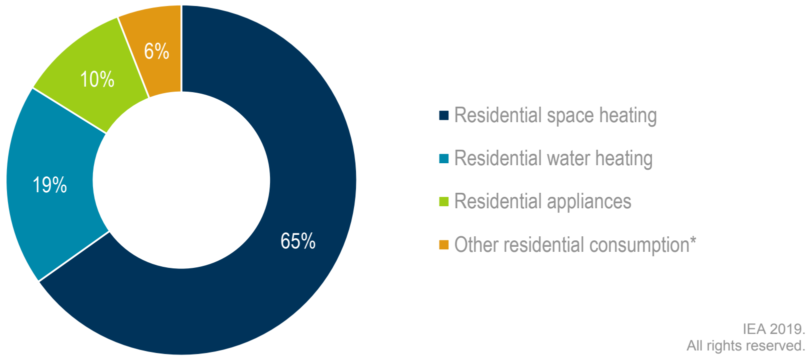
Residential and commercial energy demand has flattened to around 90 Mtoe, with natural gas, oil and electricity accounting for 83% of total energy consumption in the sectors.

*Not visible on this scale.

Note: The commercial sector includes commercial and public services, agriculture, forestry, and fishing.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Figure 4.5 Breakdown of TFC in the residential sector, 2017



Space and water heating accounts for over 80% of residential energy consumption, although energy demand for heating has decreased significantly from 2000.

**Other residential consumption* includes energy for cooking, lighting and space cooling.

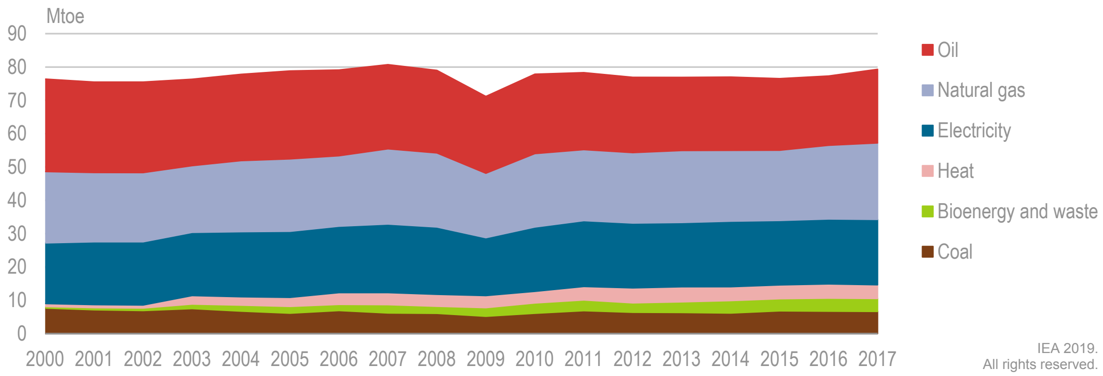
Source: IEA (2019b), *Energy Efficiency Indicators Highlights 2019*, www.iea.org/statistics.

Industry

The industry sector is the largest energy consumer in Germany, with 80 Mtoe in 2017, equivalent to 35% of TFC. The financial crisis in 2008 led to a dip in industrial energy demand, but the sector recovered quickly. In 2017, consumption was the highest since 2007. Natural gas, oil and electricity dominate energy consumption in industry (Figure 4.6). In 2017, natural gas accounted for 29%, oil 28% and electricity 25%.

The chemical and petrochemical industry accounts for the largest share of industrial energy consumption (Figure 4.7). Roughly half of the chemical industry's consumption is oil products used for non-energy purposes as raw material in the processes. Other large industrial energy consumers are steel and non-metallic minerals manufacturers.

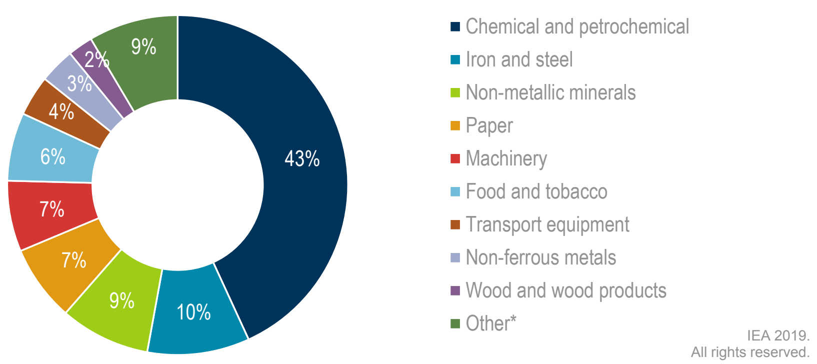
Figure 4.6 TFC in industry by source, 2000-17



Since the economic crisis in 2008, industrial energy consumption has stabilised at around 77 Mtoe to 80 Mtoe, of which oil, natural gas and electricity together account for 82%.

Notes: Includes non-energy consumption.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Figure 4.7 Energy consumption in manufacturing industry sectors, 2017



The chemical and petrochemical industry accounts for the largest share of industrial fuel consumption, even when not including fuels used for non-energy purposes.

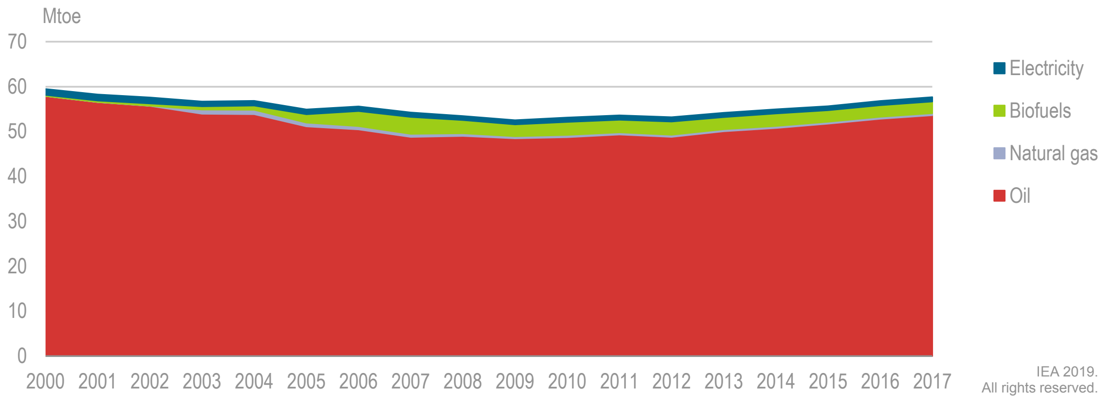
**Other* includes textile and leather, mining and quarrying, and non-specified industry consumption.
Note: Includes fuel consumption for non-energy use.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

The energy intensity of Germany's industries is falling. Measured as energy consumption per value added, total energy intensity for manufacturing industries has declined by around 20% since 2000 (IEA, 2018). This reduction can come from energy efficiency improvements or from structural changes, and the intensity development varies for different industry sectors. Energy intensity has decreased only slightly in the chemical and metals industries, while falling significantly for the machinery and transport equipment industries.

Transport

In 2017, the transport sector consumed 58 Mtoe, 25% of TFC in the country. Consumption decreased until 2009, but has since increased steadily, and was up by 10% from the 2009 level in 2017 (Figure 4.8). Road transportation (both freight and passenger) accounted for 95% of total domestic transport demand in 2017 (international aviation and navigation are not included). This was a higher share than in many other large IEA countries, including the United Kingdom (94%), Japan (88%) and the United States (85%).

Figure 4.8 TFC in transport by source, 2000-17



Transport energy demand is increasing again, after a post-financial crisis decline. The sector is dominated by oil, although biofuels have experienced volumetric growth in the last decade.

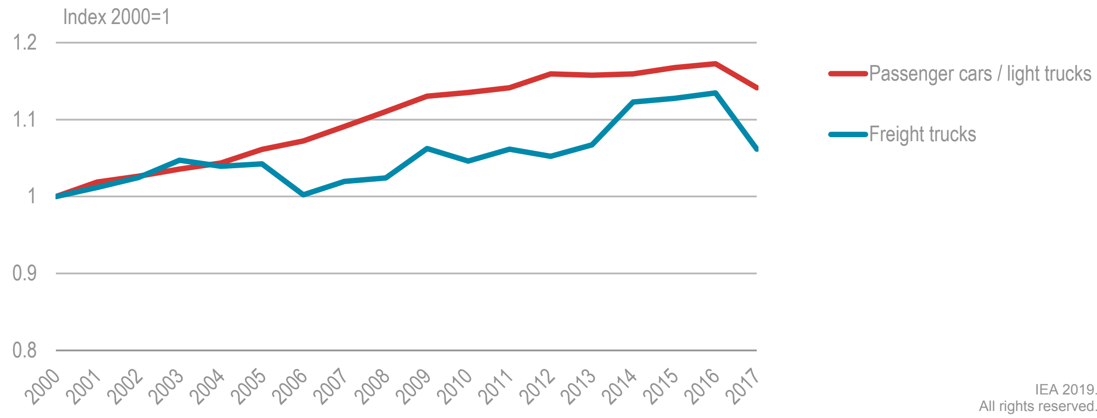
Note: The transport sector demand excludes international aviation and navigation.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Oil fuels dominate transport energy consumption, accounting for 93% in 2017. Most of this is diesel fuels, which accounted for 60% of total transport energy use in 2017, followed by 31% for gasoline. Diesel engines are more energy efficient than gasoline, but contribute to higher emissions of particulates and other pollutants. The high share of diesel in road transport has been a major contributor to air pollution in many German cities. The share of biofuels increased significantly in the early 2000s until a peak in 2007, when they accounted for 7% of total transport demand, but has since declined slightly to just below 5% in 2017.

Cars and light trucks represent around two-thirds of total transport energy consumption, and freight trucks account for most of the rest. Fuel efficiency is continuously improving, driven by stricter fuel standards in the European Union (EU). From 2000 to 2017, fuel consumption per vehicle kilometre (vkm) fell by 12% in cars and light trucks and 6% in freight trucks (Figure 4.9).

Electric vehicle (EV) sales are rapidly increasing in Germany, but the share is still very small. In 2018, around 68 000 EVs were sold in Germany, equal to 2% of total car sales (ACEA, 2019). EV charging is still too small to have any significant impact on transport energy demand, and most EV charging is done at home and registered as residential energy use.

Figure 4.9 Fuel efficiency (kilometre/litre) in road transport by mode, 2000-16



Road transport accounts for 95% of total domestic transport energy demand, and fuel efficiency has improved since 2000 for both passenger cars and freight trucks.

Source: IEA (2019b), *Energy Efficiency Indicators Highlights 2019*, www.iea.org/statistics.

Institutions

Energy efficiency programmes are mostly administered out of the Federal Ministry for Economic Affairs and Energy (BMWi), though other ministries are also involved when measures impact their respective coverage areas, such as the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU). Both the BMWi and the Federal Ministry of the Interior, Building and Community (BMI) oversee issues related to energy conservation in buildings while the Federal Ministry of Transport and Digital Infrastructure (BMVI) takes the lead on efficiency policies in the transport sector. A number of energy efficiency funding programmes are administered through the Federal Office for Economic Affairs and Export Control (BAFA).

Under Germany's federal structure of government, the *Länder* (states) and municipalities also have a considerable degree of autonomy to pursue energy efficiency policies. A formal working group, the Federal Bureau for Energy Efficiency (BfEE), was established in 2018 as part of an effort to boost collaboration and policy co-ordination between the federal government and the states.

Energy efficiency policy

Germany's Energiewende places a high degree of importance on energy efficiency, both as a means to lower greenhouse gas (GHG) emissions as well as to contain costs for households and companies. In particular, the German government views energy efficiency as a means to boost the global competitiveness of German industry. As such, the 2010 Energy Concept established targets to cut primary energy usage by 20% by 2020 and by 50% by 2050 relative to 2008 levels.

In December 2014, the German government adopted the National Action Plan on Energy Efficiency (NAPE), which outlined a set of measures to help reduce energy consumption in line with the Energiewende's targets (BMWi, 2014). The first area of focus of the NAPE is to provide consumers with information and advice on energy efficiency. The second area of focus is on promoting targeted investment in energy efficiency through incentives. The third focus area is to demand more action, including requiring large companies to conduct energy audits, and applying new standards for appliances and newly built buildings (BMWi, 2019a). The NAPE increased public financial support for energy efficiency measures to EUR 17 billion between 2016 and 2020 (BMWi, 2018).

Table 4.1 Energy efficiency targets of Germany's energy transition

Targets (from 2008 levels, except where noted)	2020	2050
Primary energy consumption	-20%	-50%
Electricity consumption	-10%	-25%
Primary energy consumption in buildings		-80%
Heat demand in buildings	-20%	
Energy consumption in transport (from 2005)	-10%	-40%

Source: Berlin Energy Transition Dialogue (2019), "Key facts about the energy transition in Germany", https://2019.energydialogue.berlin/wp-content/uploads/2019/04/betd_press_factsheet.pdf.

However, given that Germany is not on track to meet its 2020 efficiency targets, the government is currently working on a new energy efficiency strategy to cover all sectors, guided by a public consultation on the Green Paper on Energy Efficiency launched in 2016. The guiding principle will be "efficiency first" and Germany plans to define concrete efficiency measures for 2021-30 as part of a new NAPE 2.0. Additionally, the government will prepare a roadmap to support the national target to halve primary energy consumption by 2050 (compared with 2008). A special focus will be on energy demand in the heating sector and from buildings.

One of the main sources of financing energy efficiency measures and programmes in Germany is the Energy and Climate Fund (EKF), established by federal law in 2010 and financed with revenues from permit auctions under the EU Emission Trading System (ETS). Programmes range from direct financial support to information, communication measures and advisory services. In 2018, auction revenues directed EUR 2.6 billion into the fund, in addition to EUR 2.8 billion of federal budget funds that were also allocated to the fund. In addition to a wide range of energy efficiency measures that address buildings, industry, municipalities, products and appliances, and transportation, the EKF provides up to EUR 500 million to energy-intensive industries to offset costs associated with the EU ETS on electricity prices.

In addition, Germany is a leading market for energy performance contracts (EPCs), bolstered by the establishment of standardised model EPC contracts – including a pool of pre-approved providers – by, for instance, the German Energy Agency (Dena) and the Berlin Energy Agency (BEA). Several organisations provide model contracts and the BfEE maintains a complete list of model contracts. Furthermore, the government runs advisory programmes in which consultants perform checks on companies and municipalities to determine whether EPCs would help them achieve energy efficiency gains. The federal government also promotes collaboration and dialogue with the states to harmonise and improve the regulatory environment for EPCs through the Bund-Länder Dialog Energiespar-Contracting. This dialogue also funds the bolstering of contracting knowledge in the energy agencies of states as well as model projects.

Germany is also one of the top markets for energy services, which the government estimates were valued at EUR 9 billion in 2016 based on a 2017 survey. The Act on Energy Services and Other Energy Efficiency Measures requires energy suppliers to provide information to their customers on energy efficiency measures and services available to them. As part of this effort, the BfEE tracks and assesses the market for energy services. The large and diverse pool of energy service providers means that the market for advisory services and analysis is also sizeable, estimated at EUR 800 million with 13 000 to 14 000 energy consultants active in the market. Energy contracting continues to grow and stood at around EUR 7.7 billion in 2016 with 560 companies offering energy-contracting services (mainly energy supply contracting and operation and maintenance models). A further 1 100 suppliers provided EUR 435 million in energy management services in 2016.

Buildings

The Climate Action Plan 2050 targets a reduction in energy consumption from buildings of 66-67% from 1990 by 2030 through a combination of standards and financial incentives for both new and existing buildings. The government aims to achieve a “virtually” climate-neutral building stock by 2050 by cutting primary energy demand from buildings by 80%. The German government in November 2015 adopted the Energy Efficiency Strategy for Buildings, which sets out a policy plan for achieving Energiewende targets in the building sector.

Building standards

Standards are used to a greater extent for new buildings, including a minimum statutory level for renewable energy in new buildings. Germany has laid out a roadmap in the Energy Efficiency Strategy for Buildings, which sets out a comprehensive strategy for this sector. Germany wants to make its building stock virtually climate-neutral by 2050.

To achieve this target, the Energy Efficiency Strategy for Buildings includes mandatory building codes, labelling schemes, low-interest loans for refurbishments or new buildings, investment grants, and advisory and consulting services for consumers (BMWi, 2015).

The Energy Conservation Act (EnEG) and the Energy Saving Ordinance (EnEV) outline energy efficiency requirements for new buildings. On 1 January 2016, the regulatory minimum requirements regarding primary energy for newly constructed buildings were increased by 25%. For the building envelope, the requirements were increased by around 20% (BMWi, 2019b). The Renewable Energies Heat Act (EEWärmeG) outlines a plan to increase the share of renewable energy in heating to 14% by 2020 (IEA, 2019c). The government expects to shortly merge the regulations included in the EEWärmeG, EnEG and EnEV into a new act, the Buildings Energy Act, to consolidate and streamline compliance requirements for energy performance in new buildings. The Buildings Energy Act will implement the requirements of the EU Energy Performance of Buildings Directive, thereby keeping the current energy standards for new and existing buildings in force. Furthermore, integrated district approaches will be implemented.

The government runs the CO_2 Building Renovation Programme, which provides financial incentives for energy-efficient renovations, such as low-interest loans and repayment and investment grants, through the state-owned promotional bank, KfW. In order to qualify for funding, homeowners and other facilities need to demonstrate that they exceed legal energy efficiency requirements as set out in the EnEV. The programme's 2017 budget was EUR 2 billion, the bulk of which was used for low-interest loans; around 400 000 projects received funding in 2017. Under the programme, KfW covers up to 30% of the cost of renovations; greater energy savings from refurbishment qualify for higher levels of funding. BMWi estimates that one out of three retrofits of homes benefits from KfW funding. For the time being, Germany does not provide financial incentives in the form of tax breaks to households or businesses for energy efficiency renovations, though such incentives were proposed as part of the climate cabinet's recent package of measures (see Chapter 3 on climate change).

Information campaigns

The federal government offers a number of advisory support and information campaigns to households, companies and municipalities on improving energy efficiency. Among these, a particular success story has been the Deutschland Macht's Effizient (Germany Makes It Efficient) campaign, which provides, among other things, a free hotline, mainly to households, to educate them about funding options for energy efficiency improvements (BMWi, 2019a). In addition, the government operates consumer centres that provide online and telephone advice, as well as advisory sessions and home appointments. As part of this, experts offer "energy checks" to homeowners and tenants.

Heating

The Heating Cost Ordinance, originally passed in 1989 and last updated in 2009, introduced consumption-based billing for heat and hot water to encourage consumers to reduce their level of consumption.

The government also uses colour-coded efficiency labels as part of the EU Energy Labelling Regulation on heating systems and boilers. Since January 2016, Germany has used an updated efficiency label on boilers of more than 15 years in age, along with information on advisory and funding services available to switch to more efficient systems. The government also offers "heating checks" in which energy efficiency consultants visit homes to provide recommendations on using energy more efficiently. However, households have generally shown reluctance to upgrade their heating systems.

Financial incentives are the primary instruments that Germany employs to help improve efficiency in the heating sector. The government launched the Energy Efficiency and Heat from Renewables Strategy over 2017-20 to restructure various support programmes to target audiences on a thematic basis more specifically. The focus areas include: 1) energy-efficient buildings; 2) energy efficiency in industry and commerce; 3) heating infrastructure; and 4) saving electricity in private households. As part of this effort, the government has created a one-stop shop for information on the programmes to potential beneficiaries.

The Market Incentive Programme (MAP) provides EUR 320 million annually, in the form of investment or repayment grants to supplement low-interest loans, towards investments in renewable heating and cooling installations, including solar thermal, heat pumps and biomass installations.

The government introduced the Energy Efficiency Incentive Program (APEE) in January 2016, which provides additional financial incentives for efficient ventilation and heating installations, including incentives to replace inefficient oil and gas heating systems with more efficient ones. Fossil fuel heating systems are funded through grants or loans under the KfW Energy-Efficient Modernisation programme, while renewables heating systems are funded through the MAP. In August 2016, the APEE programme was extended to include innovative fuel cell heating systems.

The government in 2016 also introduced the Heating Optimisation Programme, a promotion scheme to subsidise up to 30% of the costs of exchanging heat pumps and installing hydraulic balancing systems to further boost efficiency.

Germany is keen to pursue more sector coupling, to increase the share of heating sourced from renewables-based electricity. Though large-scale electrification of heating can pose challenges to the electricity grid, through sector coupling it can also bring opportunities for improving efficiency in the energy system overall. However, high electricity costs, driven by high taxes (including the Renewable Energy Sources Act [EEG] surcharge to subsidise renewables) are impeding opportunities to use more electricity in the heating sector, especially in a context of low taxation on fossil fuels (also see Chapter 3 on climate change and Chapter 5 on renewables).

The use of district heating in Germany is relatively minor compared with several other European countries, though it is becoming increasingly important in urban areas (see Chapter 3 on climate change). District heating systems are usually operated by municipal utilities. The district heating market is unregulated and the supplier sets the price. More than two-thirds of district heat is produced in co-generation[7] plants, which also provide around 20% of Germany's total electricity generation. Since 2002, the CHP (Combined Heat and Power) Act provides support for co-generation through a bonus payment on sold electricity (though the subsidy is more pertinent for industrial co-generation rather than district heating). The act was revised in 2016, with funding extended up to 2022. Germany also supports investments in modern district heating systems. In 2017, the government introduced the Heating Network Systems 4.0 programme, which provides investment grants for heating infrastructure with low temperatures (20°C to 95°C) and high shares of renewable energy and waste heat. The programme is currently scheduled to run until 2021, but is expected to continue beyond that date.

Smart meters

The Energy Efficiency Strategy for Buildings highlights the critical role that digitalisation can play in cutting energy consumption and meeting efficiency targets. Moreover, the European Union's third internal market directives on gas and electricity call on member states to equip 80% of consumers with smart meters by 2020. However, Germany commissioned a cost-benefit analysis in 2013 that determined a more concentrated initial roll-out to be economically reasonable (BMWi, 2017).

In 2016, the federal parliament passed the Act on the Digitalisation of the Energiewende, which stipulates the installation of smart meters as well as their technical requirements. The act calls for a phased roll out of smart meters, with larger consumers and generation facilities slated to be the targets of the first stage (BMWi, 2019c). Specifically, consumers with energy consumption of more than 6 000 kilowatt-hours (kWh) per year (the average

[7] *Co-generation* refers to the combined production of heat and power.

German household consumes around 3 500 kWh per year) and generators of more than 7 000 kW of annual capacity are slated to be fitted with smart meters by 2020. The smart metering infrastructure buildout is referred to as the Smart Meter Gateway (BSI, 2017).

Data security has been a paramount concern related to smart meters in Germany, prompting the Bundestag to include the most stringent data protection rules in Europe as part of the Act on the Digitalisation of the Energiewende. As critical infrastructure, the act required certification of smart meters by the Federal Office for Information Security (BSI), which issued its first certificate in December 2018 (BMWi, 2019d). Mandatory deployment can begin after three manufacturers of smart meters receive certifications (currently eight applications are under review). As such, the roll-out of smart meters has so far been slowed down by delays in technology development and certifications for technology.

In 2016, the government launched the Energy-Savings Meter pilot programme to facilitate the development of digital metering systems. Under this programme, BAFA provides up to EUR 1 million in funding per project to companies that provide customers with metering infrastructure, energy data and advice on energy savings. Thus far, uptake for the programme has been a notable success. In the first pilot phase, the full funding amount of EUR 60 million was disbursed over two years. The second phase of the pilot programme, with funding of EUR 100 million, launched at the end of February 2019 and will run through the end of 2022.

Appliances and lighting

The EU Ecodesign Directive establishes an EU-wide minimum energy efficiency requirement on products, including household appliances and lighting. The EU Energy Labelling Regulation supplements the Ecodesign Directive with mandatory labelling requirements for appliances (European Commission, 2019a). The European Union's obligations are directly applicable to manufacturers, suppliers and dealers without national implementation. Rather, national implementation of these two instruments is limited to market surveillance, which is conducted by the *Länder* in Germany.

In an effort to bolster consumer uptake of efficient appliances, the BMWi operates the National Top Runner Initiative, which provides consumers with targeted information on energy-efficient products and energy savings. It also provides information services to retailers to improve their expertise in selling energy-efficient products as well as support to producers to help them develop innovative energy-saving products.

Industry

Though Germany has energy efficiency targets for the buildings and transport sectors, it does not define discrete targets for the industry sector; rather, it has successfully applied incentives and voluntary mechanisms. German industry to date is relatively energy efficient from a global perspective.

Several incentive programmes are in place to increase energy efficiency in the industrial sector. A new funding programme was launched in 2019 to encourage enterprises to invest in energy efficiency. Funding support is provided for cross-sectoral technologies, process heat generated by renewable energy, measurement and control technology to be integrated in an energy management system, and energy management software. In addition, the government provides financial support for enterprise-specific measures that increase the energy efficiency of the entire production process. This includes investments to avoid waste heat as well as measures for the first-time utilisation (internally or externally) of waste heat; small and medium-sized enterprises (SMEs) benefit from higher funding rates under this programme.

According to the EU Energy Efficiency Directive from 2012, non-SMEs are required to perform an energy audit every four years. Notably, following an amendment of the corresponding law, obliged companies will be required to report the key results of their energy audits to an online (non-public) government database, which will enable better enforcement and evidence-based policy making. Companies that already have an energy management system or environmental management system in place, an estimated 30% of non-SMEs in Germany, are exempt from the energy audits. However, there is no formal follow-up process in place from the audits requiring companies to implement their recommendations (though energy efficiency networks, described below, create a platform to help companies enact recommendations).

The ISO registers that 14 736 German sites have received ISO 50001 certifications, which account for approximately 30% of ISO 50001-certified sites globally. Among the incentives provided to encourage ISO 50001 certification are exemptions from the EEG levy and eco-tax for companies that enact energy management systems, as well as a promotional scheme for the introduction and retention of ISO 50001 in SMEs (BMWi, 2018). However, there was a significant drop in new certifications recorded in 2017, according to IEA data.

In December 2014, the federal government (led by BMWi and BMU) set up an alliance with approximately 20 business associations and organisations to establish energy efficiency networks nationwide (BMWi, 2019f). Energy efficiency networks comprise 8 to 15 companies that receive energy savings advice and recommendations from an energy consultant. Based on the analysis, each company establishes an energy savings target, backed up with an action plan. The alliance has a target to set up around 500 networks by 2020 (BMWi, 2018). The networks have helped drive efficiency improvements in industry through a structured peer-to-peer process.

Transport

Germany applies EU fuel efficiency and vehicle emissions standards to its automobiles. By 2021, phased in from 2020, the fleet average to be achieved by all new cars is 95 grammes of carbon dioxide (CO_2) per kilometre (gCO_2/km). This equates to fuel consumption of around 4.1 litres per 100 kilometres (L/100 km) of petrol or 3.6 L/100 km of diesel. The previous 2015 target of 130 gCO_2/km corresponds to fuel consumption of around 5.6 L/100 km of petrol or 4.9 L/100 km of diesel.

The Motor Vehicle Tax Act (KraftStG) was amended in 2009 to account for CO_2 emissions and encourage the purchase of passenger cars with low CO_2 emissions. These changes included the addition of a tax-free threshold for CO_2 emissions. Vehicles registered between 1 July 2009 and 31 December 2011 were exempt from the motor vehicle tax for emissions of 120 gCO_2/km or lower, a level that was reduced to 110 gCO_2/km for cars registered in 2012 and 2013. The limit was further reduced to 95 gCO_2/km for cars registered from 2014.

Since 2011, under the Ordinance on Energy Consumption Labelling for Passenger Cars (CarEnVKV), the government has required car manufacturers and dealerships to attach labels that include information on fuel consumption and CO_2 emissions. The labels include a comparison of CO_2 efficiency with other vehicles based on a colour-coded scale, ranging in rankings from A+ (highly efficient) to G (inefficient) (BMWi, 2019e). The labels also include information on electricity consumption for EVs. The CarEnVKV is currently being revised to reflect the new methodology under the Worldwide Harmonized Light Vehicle Test Procedure – a change that is expected to take effect in the first quarter of 2020 – motivated by emissions cheating scandals in which automakers were using illegal defeat devices to pass emissions tests.

Unlike many other countries, Germany imposes speed limits only on parts of its highways. Given that fuel efficiency falls sharply at higher vehicle speeds, actual efficiency can differ significantly from measured efficiency on German highways, where cars often run at high speeds. Most EU member states impose speed limits of 120 kilometres per hour to 130 kilometres per hour (European Commission, 2019b).

The German government is also keen to promote the uptake of intermodal transport systems through additional funding, including in collaboration with private-sector infrastructure. To date, investments in and consumer uptake of public transportation has lagged behind that in many other European countries. To help address this gap, in 2018, the government published a new funding guideline for EUR 500 million until 2023 to promote energy efficiency measures in the rail transport sector.

The task of reducing energy consumption and emissions from the transport sector is made more urgent due to rising air pollution in major cities and the “diesel-gate” scandal, in which car companies were found to be cheating on emissions tests. Several cities have put in place bans on diesel cars as a result of air pollution-related legal challenges (see Chapter 3 on climate change).

Electric vehicles

A shift toward EVs will also help improve transport sector energy efficiency. In order to address the lack of progress on transport emissions reduction, the government first launched the National Platform on Electric Mobility (NPE) in 2010 to develop market-based measures that will help transform Germany by 2020 into a leading producer and market for electric mobility systems. The task force was composed of representatives from industry, academia, government, labour unions and civil society. The NPE recommended an approach focused on significantly expanding research and development (R&D) by the industry, supported by governmental financial assistance, as well as promoting skills training, technology standardisation, and cross-sectoral technological integration. The NPE also recommended complementing these efforts with incentives to build out charging infrastructure and to encourage consumer uptake of electric cars, including fiscal incentives, low-interest loans, and priority lane and parking access.

To foster the use of EVs, the German government has implemented supporting fiscal measures. Specifically, the government grants a ten-year tax exemption for all-electric vehicles, staring with vehicles registered from 18 May 2011 through the end of 2020.

In addition, it offers a EUR 4 000 purchase grant for non-hybrid EVs and a EUR 3 000 purchase grant for plug-in hybrids with a list price of up to EUR 60 000 (up to a total funding limit of EUR 1.2 billion) (BMWi, 2019g). The federal government and the auto industry evenly split the cost of the subsidy.

The government also provides EUR 300 million in funding towards building out EV charging infrastructure. Of this amount, EUR 200 million is granted for rapid charging infrastructure and EUR 100 million for standard charging points. The government also supports R&D activities in the area of advanced vehicles, including hydrogen and fuel cell vehicles. It has an aspirational target for at least 20% of new cars procured for the federal government's vehicle fleet to be electric. Starting in January 2019, the government started offering tax relief for company EVs purchased or leased between 1 January 2019 and 31 December 2021.

Beyond the passenger vehicle segment, the federal government also offers funding for heavy-duty trucks with alternative drivetrains, including battery electric and fuel cells. It also grants toll exemptions for electric trucks since January 2019 and R&D funding.

Still, the transportation sector has proven to be the most challenging sector to meet emissions reduction and efficiency targets. The government launched the task force on emissions reduction in the transportation sector, called the National Platform Future of Mobility (NPM), as a successor to the NPE in 2018 to make recommendations on addressing transport sector emissions and efficiency (see Chapter 3 on climate change). The Climate Action Programme 2030 inlcuded a CO_2 tax on transport emissions, which would raise fuel prices and likely motivate improvements in transport efficiency.

Assessment

Germany's effort to tie its energy efficiency strategy with its climate strategy is an effective way to ensure that energy and climate policies are aligned towards common goals. In fact, according to the Climate Action Plan 2050, industrial emissions fell from 283 million tonnes of CO_2 equivalent in 1990 to 181 million by 2014, while buildings emissions fell from 209 million tonnes to 119 million over the same period, the largest drops of any sectors. In contrast, transport emissions experienced a much more modest decline from 163 million tonnes to 160 million.

Despite notable progress in decoupling energy demand from economic growth, Germany is falling short of meeting its energy efficiency targets. The 2010 Energy Concept established targets to cut primary energy usage by 20% by 2020 and by 50% by 2050 relative to 2008 levels. By 2018, Germany had achieved a reduction in primary energy usage of around 10%, placing it far off a trajectory to meet the 2020 target and putting at risk achievement of its 2020 GHG reduction target.

Germany has pursued a number of policies to cut energy usage from buildings and industry, which have borne results. However, in order to achieve additional reductions, new and more ambitious measures will be required to meet both near- and long-term targets.

The starting point for the government is that avoided energy usage is an economically advantageous way to achieve its emissions reduction targets. The NAPE was a central plank under the 2020 Climate Action Programme. The NAPE included a policy mix of standards, incentives and information-sharing campaigns that are considered to be an effective combination to achieve results. However, the measures heavily focused on buildings and industry rather than transportation.

Looking to medium-term targets, the government's new "efficiency first" focus can help it achieve greater results over the coming decade and beyond. The government plans to issue an updated NAPE 2.0 as well as a 2050 roadmap on energy efficiency that will underpin future progress. As part of this effort, identifying medium-term targets for efficiency (e.g. 2030, 2040), in line with climate targets, will help ensure that the policy pathway is aligned with goals. Faster clarity on more ambitious policy and regulatory frameworks is essential to avoid locking in current technologies and to facilitate investments necessary to meeting targets. As the end of 2020 fast approaches, the focus on 2030 and beyond will become more important and the sooner the government can define its strategies and policies, the more progress it will likely make, to avoid having to "catch up" to targets closer to deadlines, or risk missing them.

Germany, which has made commendable progress to date on improving building efficiency, is among the leaders in Europe in terms of setting new building standards and offering financial incentives for energy savings. Moreover, the renovation roadmap for buildings has proven effective at helping households understand the benefits of energy savings and implement upgrades. Still, more work lies ahead in order to achieve buildings targets. Germany's zero-energy building standard for new buildings by 2021 will help achieve progress, but a more focused effort on upgrading the existing building stock is also required. In particular, Germany needs to promptly strengthen its measures to minimise barriers and market failures that hinder energy efficient renovations. The government can lead by example in increasing the rate of renovation in public buildings, building off a programme that has provided roadmaps for non-residential municipal buildings since 2016.

Moreover, Germany will need to devote more resources towards moving away from fossil fuels for heating (and cooling, which may become more prominent in future years with climate change), including through stronger incentives and assistance for upgrading and expanding heating networks. Additional consumer education efforts to streamline and clarify incentives for upgrading heating systems can help in this regard. Due to high levies on electricity and relatively low taxes on heating oil and natural gas for heating, fuel switching and sector coupling between electricity and heat are hampered.

Germany has several measures to promote the development of district heating, which can be a more efficient and renewables-based option for providing heat, depending on the fuel source (currently over 70% comes from non-renewable resources). The government's incentives for district heating networks are structured to offer more assistance to systems that generate heat from renewable resources. In addition to the direct use of renewable fuels, encouraging the use of industrial waste heat and large-scale heat pumps can minimise the carbon intensity of district heating networks and increase sector coupling.

Though a smart meter roll-out in Germany has lagged behind those in other advanced economies, the Smart Meters Operation Act that took effect in 2016 has resulted in more installations since 2017. Additional installations are expected by 2020, when all users consuming more than 6 000 kWh per year must be fitted with smart meters. However, given that the average German household consumes only around 3 500 kWh per year, most households would not be fitted with smart meters under this plan on an obligatory basis. Beyond electricity, the Smart Meter Gateways being installed can also be used for the metering of gas, water and heat consumption, creating additional benefits for consumers. Overall, smart meters will be instrumental to long-term efficiency gains in the buildings sector. In addition, as Germany looks towards flexibility solutions to manage the growth in variable renewables generation on its grid, digitalisation of buildings may play an important role in balancing demand and supply.

Germany has a highly developed market for energy services, with a large number of providers and contract types, which has opened up more demand for advisory services. Demand for these services has been boosted by government efforts to ensure more information dissemination to end users, including through energy efficiency networks. BfEE maintains a public list of providers to ensure accountability to consumers.

EPCs have been a particular success story in Germany, where it is a leading market in Europe. In particular, under the leadership of the BEA and Dena, Germany's establishment of model contracts for EPCs has standardised offerings and increased trust and transparency in the marketplace. The government should work to sustain and build on momentum to date in these areas.

For appliances, Germany implements the EU Ecodesign regulation to establish standards and labelling requirements for products.

Similar to buildings, Germany has achieved notable progress on reducing energy usage in the industrial sector, which is the largest energy demand sector in the country. German companies have achieved high levels of ISO 50001 certifications. Moreover, Germany follows the EU Energy Efficiency Directive, requiring energy audits of non-SMEs every four years. Thus far, 30% of non-SMEs have implemented energy management systems. The government could further explore options for promoting more implementation of energy management systems beyond the requirement for energy audits.

The transportation sector has been the most challenging one for Germany to cut energy usage. In fact, energy usage in transport increased by 10% from 2009 to 2017, the bulk of which comes from diesel-fuelled road transportation. From a policy perspective, Germany applies EU fuel efficiency and vehicle emissions standards to its automobiles; they are among the leading standards in the world. Moreover, tax benefits that the German government provides to encourage the purchase of passenger cars with lower CO_2 emissions can help shift consumer preferences towards more fuel-efficient vehicles. The German government also has in place fiscal incentives to support the purchase of EVs, though consumer uptake has been very low.

Still, Germany's diesel usage remains high and is contributing to air pollution in major cities, some of which have taken steps to impose bans on diesel cars. While outright bans on diesel cars can create challenges for daily commuters, Germany has an opportunity to capitalise on its strong automotive industry to push more ambitious alternative fuel policies. In particular, as German carmakers are already reorienting their production lines towards electric models, policy support can complement these efforts to promote more consumer uptake of EVs, along with the necessary charging infrastructure. In addition, the government should co-ordinate with industry to support innovation to cut fuel consumption and emissions from the long-haul trucking sector. Expanding and upgrading public transport and cross-country rail infrastructure can also help reduce fuel usage in road transportation.

Recommendations

The government of Germany should:

- Assign top priority to expediting the development of energy efficiency policy and regulatory frameworks for all sectors to enable necessary investments to close the gap on efficiency targets; define medium-term targets towards 2050 goals.
- Reform and strengthen the measures targeting energy efficiency in buildings to increase the rate of renovation of existing buildings.
- Accelerate and expand the smart meter roll-out to all households, and enable the long-term digitalisation of the buildings sector to achieve energy savings and unlock flexibility of demand.
- Ensure a level playing field among different fuel types to encourage the shift from inefficient fossil fuel boilers to more efficient heating systems, including renewables.
- Update efficiency policy tools for industry to achieve more ambitious outcomes, including compulsory implementation of the identified energy savings opportunities from energy audits.
- Adopt a more comprehensive approach to promote reduced energy demand in transportation, including stronger incentives for consumer uptake of EVs and promotion of public and multimodal transport options.

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5. Renewable energy

Key data

(2018 provisional)

Total supply: 42.2 Mtoe (14.1% of TPES) and 227.2 TWh (35.3% of electricity generation)

IEA average: 10.2% of TPES and 25.6% of electricity generation

Bioenergy (including renewable waste): 26.0 Mtoe (8.7% of TPES) and 51.2 TWh (8.0% of electricity generation)

Solar: 4.7 Mtoe (1.6% of TPES) and 44.2 TWh (7.2% of electricity generation)

Wind: 111.6 TWh (17.3% of electricity generation)

Hydro: 18.0 TWh (2.8% of electricity generation)

Geothermal: 0.3 Mtoe (0.1% of TPES) and 0.2 TWh (0.03% of electricity generation)

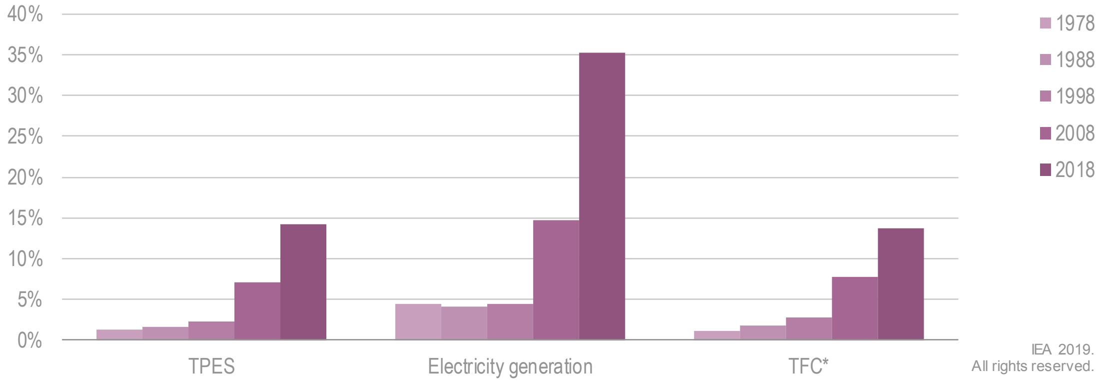
Overview

Renewable energy is at the core of the German energy transition. In recent decades, the share of renewable energy has increased from very minor levels to 14% of total primary energy supply (TPES) and 14% of total final consumption (TFC). The most impressive growth has taken place in electricity generation, where renewable energy increased from below 5% in 1998 to 35% in 2018 (Figure 5.1). Germany was a leading country in developing rooftop solar photovoltaics (PV) and is also a world leader in biogas power, but in recent years the growth has been dominated by wind power.

While renewable energy is growing rapidly in electricity generation, it is lagging behind in other sectors. Germany is not on track to meet its target of 30% renewable energy in TFC by 2030 and needs a clear strategy for increasing renewables in transport, buildings and industry. One solution would be to use growing renewable electricity to decarbonise other sectors, including heating and transport. However, development in these areas has been slow, partly explained by the existing fuel and electricity taxation regimes, which act as a barrier to efficient sector coupling, most notably for heating and cooling.

With the ongoing phase-out of nuclear power and the planned phase-out of coal power, the importance of renewable electricity will grow further, putting further pressure on the power system. Germany will need to improve infrastructure to enable continued growth in variable renewable electricity and design policies that better support reliable and efficient system integration of these resources.

Figure 5.1 Share of renewable energy in the German energy system, 1978-2018



Renewable energy supply has increased rapidly in the last two decades, most visibly in the electricity sector.

*The TFC share includes direct final consumption plus indirect consumption of renewable heat and electricity. Latest data are from 2017.

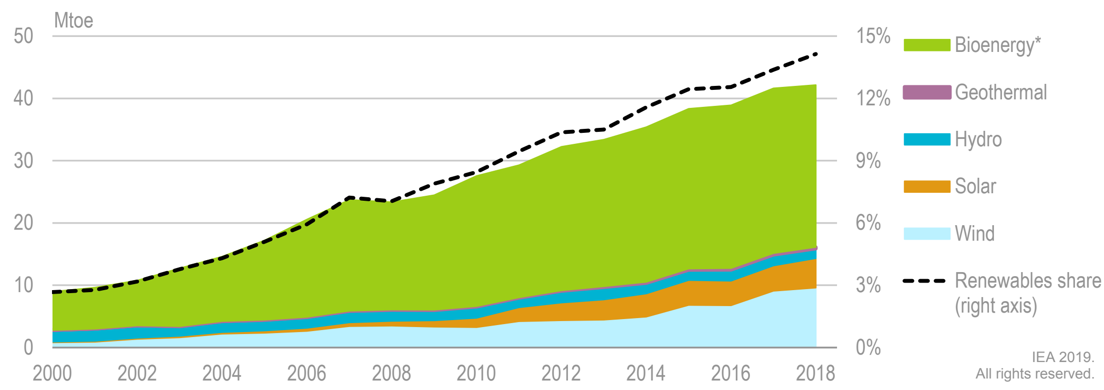
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Supply and demand

Renewable energy in TPES

Starting in the early 2000s, Germany experienced impressive growth in the share of renewable energy in TPES. From 2008 to 2018, the share increased from 7% to 12%. Back in 2000, the share was only 3%. Initially, this was driven by growth in bioenergy supply, which has dominated the renewables contribution to TPES (Figure 5.2).

Figure 5.2 Renewable energy and waste in TPES, 2000-18



Wind and solar power have increased rapidly in the last decade, but bioenergy still accounts for the largest share of renewable energy in primary energy supply.

* *Bioenergy* includes solid primary biofuels, liquid biofuels, biogases and renewable municipal waste.

Note: Mtoe = million tonnes of oil equivalent.

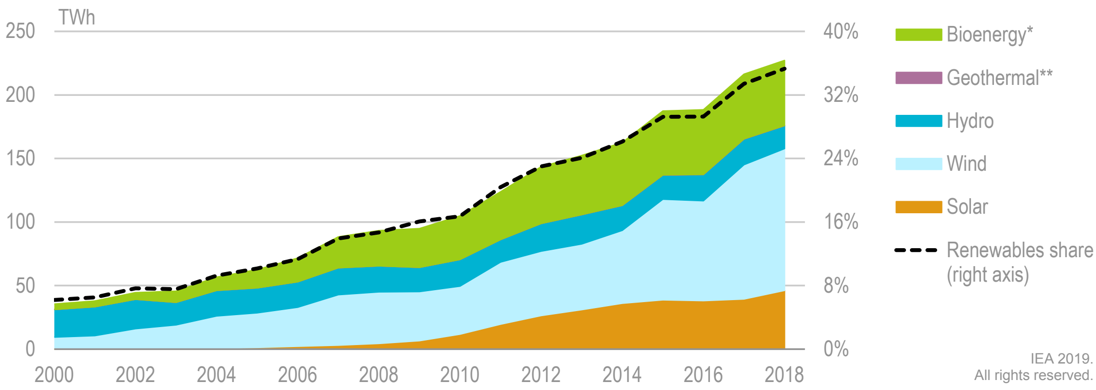
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

In 2018, bioenergy accounted for 8.7% of TPES. This includes the contributions of solid biofuels, biogas, renewable waste and transport biofuels. Nearly half of bioenergy is used for heat and power generation, and another large share is used in residential boilers. Biogas in particular is large in Germany compared with other countries (Box 5.1). In the last decade, the growth in bioenergy has stabilised somewhat, and the main increase in renewables has come from solar and wind power installations.

Electricity from renewable energy

Germany has rapidly increased the share of renewable energy in electricity generation in the last decades, driven by strong policy support. In 2018, renewable energy accounted for 35% of total electricity generation, up from 15% in 2008 (Figure 5.3). Initially, FiTs drove the growth in renewable electricity, fostering growth of wind since the early 2000s. In the period 2009-12, Germany saw a boom in PV installations, in particular in distributed generation plants in the commercial sector. After government intervention to control subsidy costs, growth of solar PV has considerably slowed down and solar power generation has roughly stabilised since 2015 at around 40 terawatt-hours (TWh) (around 6% of total generation), but reached record levels at 46 TWh in 2018. Electricity production from bioenergy also increased rapidly in the early 2000s but has since stabilised at a level just below 60 TWh (around 8% of total electricity generation).

Figure 5.3 Renewable energy and waste in electricity generation, 2000-18



Renewable electricity has doubled in seven years and covers a third of total electricity generation in 2017, with wind power accounting for most of the growth in recent years.

* *Bioenergy* includes solid primary biofuels, liquid biofuels, biogases and renewable municipal waste.

** Not visible on this scale.

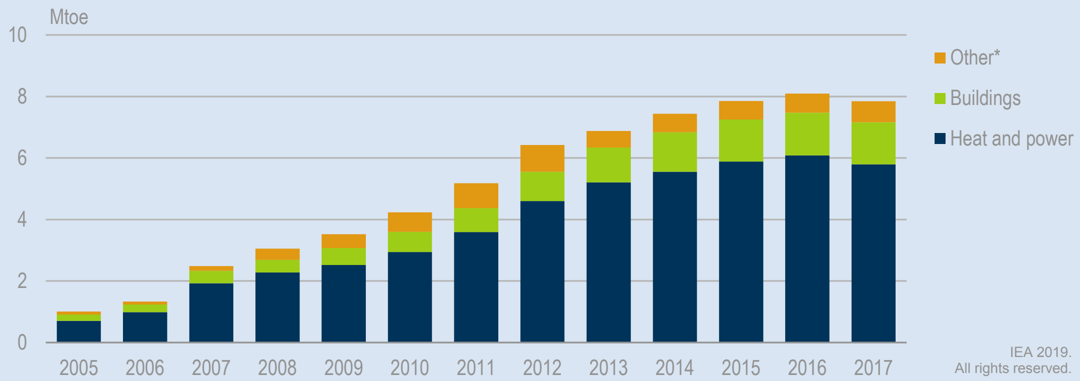
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Pilot auctions were introduced in 2015 and then implemented at full scale as of 2017, replacing FiTs, which remain only for small installations. In recent years, wind power has become the dominant source of growth in renewable electricity in Germany. Wind was the largest renewable electricity source with 112 TWh in 2018, doubling in only four years. Wind and solar together accounted for 25% of total power generation in 2018, the fourth-highest share in an IEA comparison. As a consequence, policies fostering a secure and cost-effective system integration of variable renewables are strongly prioritised in Germany nowadays.

Box 5.1 Germany is a world leader in biogas

With an annual output at around 8 Mtoe, Germany is the second-largest biogas producer in the world after the People's Republic of China and by far the largest producer among International Energy Agency (IEA) members. In the Renewable Energy Sources Act from 2000, Germany provided feed-in tariffs (FiTs) for electricity from biogas, which led to strong market growth. Production increased eightfold in a decade from 2005 to 2015, but has stalled since, as policies have changed towards market-based auctions, with FiT support available only for plants with capacity below 100 kilowatts (kW). As a result of the FiTs, most biogas is used in heat and power generation. In 2017, biogas accounted for 5% of total power generation and 28% of all gas power. Roughly 15% of biogas is used in the residential and commercial sectors, where it contributes to decarbonising heat supply in buildings.

Figure 5.4 Biogas consumption by sector, 2005-17



Germany produces more biogas than any other IEA member country, most of it used for heat and power generation or in residential and commercial buildings.

* Mainly gas consumed in the production process and small shares used in industry and transport.

Source: IEA (2019a), *World Energy Balances 2019,* www.iea.org/statistics/.

The development of Germany's biogas industry was largely based on the use of agricultural feedstocks, with a significant contribution from energy crops. More recently, policy support has evolved, focusing on smaller-capacity plants using manure feedstocks that offer higher levels of emissions reduction, deliver waste management benefits and avoid competition with food production.

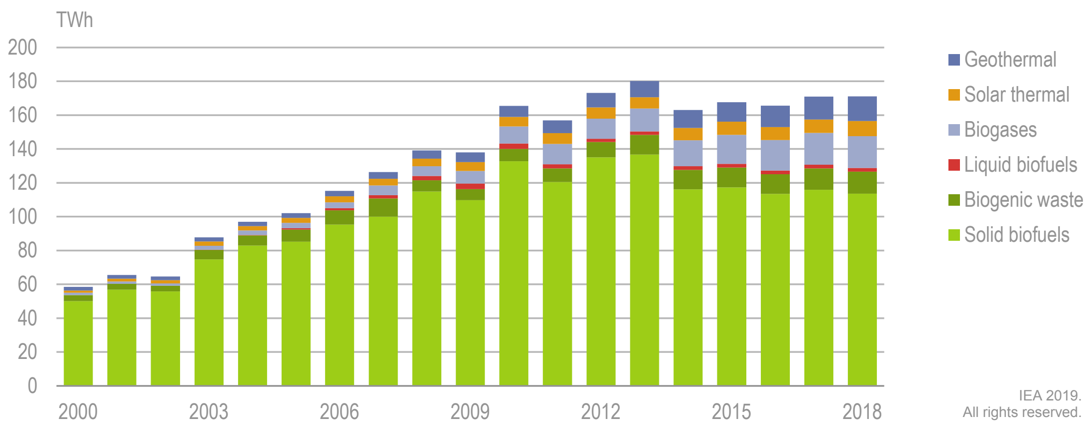
Germany's biogas industry is currently in transition. Less generous policy support combined with the generally higher costs of electricity generation from biogas compared with other renewable technologies has seen annual additions to renewable electricity capacity slow. In addition, there is a pressing need to increase the use of renewables and lower greenhouse gas (GHG) emissions in heat and transport. These factors are likely to increase focus on upgrading of biogas to produce biomethane, which can subsequently be injected into natural gas networks or used as a fuel in vehicles. Germany is also a global leader in biomethane production.

Renewable heat

The growth pattern for renewable heat in Germany is quite different from renewable electricity. While final energy consumption for heat generation based on renewable energy sources almost tripled between 2000 and 2010, it has stalled since then (Figure 5.5). Biomass fuels in various forms (solid, liquid, gaseous and biogenic fraction of waste) dominate renewable heat consumption, with solar and geothermal accounting for just around 13% of the total.

The share of renewables in final energy consumption for heating and cooling was 14.2% in 2018, thus meeting the European Union (EU) 2020 target (European Commission 2009).

Figure 5.5 Final energy consumption for heat generation based on renewable energy sources, 2000-18



Renewable heat in Germany almost tripled between 2000 and 2010, but has remained relatively stable since then, with slight annual fluctuations.

Source: BMWi (2019), "Development of renewable energy sources in Germany in the year 2018".

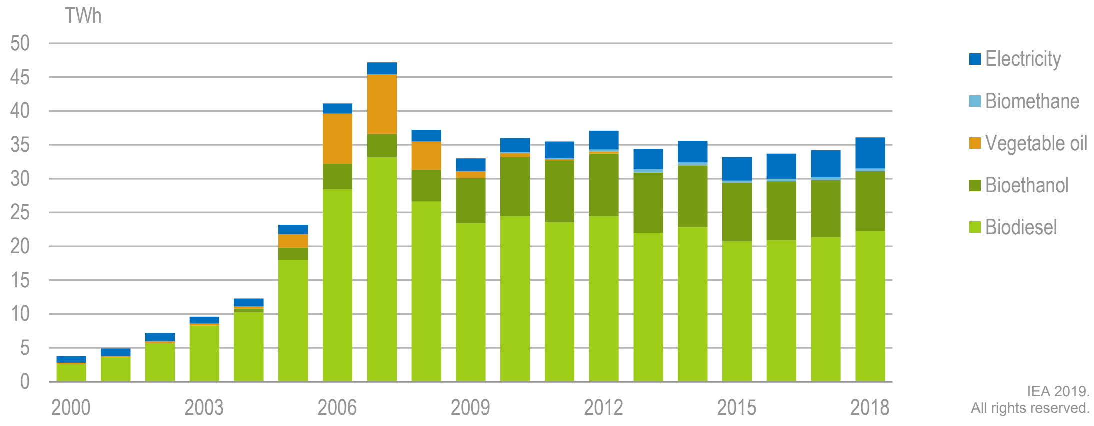
Renewable transport

Final energy consumption for transport based on renewable energy sources in Germany grew more than tenfold between 2000 and 2007, driven by rapid growth of biofuels, in particular biodiesel. However, since 2008 the level of consumption based on renewables has remained basically stable, with the increase of renewable electricity compensating for the decline of liquid biofuels (Figure 5.6). Despite the strong development of biogas in Germany, the contribution of biomethane in the transport sector has remained very small.

The share of renewables in final energy consumption in transport in 2018 was only 5.2% in energy terms. Even taking into account the EU methodology – which allows for double-counting of renewable electricity,[8] leading to a share of 7% – the gap with the 10% EU target remains significant and Germany is likely to miss its 2020 targets. Much stronger policy efforts will be needed in the future for Germany to implement an incisive decarbonisation of its transport sector.

[8] Under the EU RED methodology, renewable electricity and certain biofuels from waste and residues are eligible for double-counting against the EU target.

Figure 5.6 Final energy consumption for transport based on renewable energy sources, 2000-18



Final energy consumption for transport based on renewable energy sources grew more than tenfold between 2000 and 2007 but has remained basically stable since 2008.

Source: BMWi (2019), "Development of renewable energy sources in Germany in the year 2018".

Institutions

From the federal government's perspective, the Federal Ministry for Economic Affairs and Energy (BMWi) has overall responsibility for the area of renewable energy in Germany, and is assisted in this role by two state bodies that fall under its banner, namely, the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway (Bundesnetzagentur) and the Federal Office for Economic Affairs and Export Control (BAFA) as well as units from the Federal Environment Agency (UBA).

In accordance with the Renewable Energy Sources Act (EEG), the Bundesnetzagentur publishes monthly the new renewable energy installations that were entered into the core energy market data register and monitors the nationwide equalisation scheme process for financially supported renewable electricity among the transmission system operators (TSOs) and distribution system operators (DSOs) on the one side, and the electricity suppliers on the other.

Renewable energy policy is co-ordinated within the federal government by the BMWi with all other relevant departments, such as the Federal Ministry for Environment, Nature Conservation and Nuclear Safety (BMU), which oversees achievement of the federal government's climate protection goals.

There is also a division of labour between national government authorities and the federal states (*Länder*). Responsibility for central funding instruments, such as the EEG, the Renewable Energies Heat Act and the regulations on the biofuels quota, falls under the remit of the central government, while the *Länder* authorities are tasked with regional planning and approval procedures. The *Länder* authorities are also responsible for implementing the Renewable Energies Heat Act.

The German Energy Agency (Dena) acts as a centre of excellence for energy efficiency and renewables. Dena's two equal shareholders are the federation and the state-owned KfW banking group.

Other state authorities with an important function include the Federal Statistical Office (StBA) and the Statistical Offices of the German *Länder*, which collect energy data on the basis of the Energy Statistics Act. Among other tasks, BAFA implements measures to promote renewable energies and energy efficiency. The Working Group on Renewable Energies Statistics (AGEE-Stat – formed by the BMU, BMWi, Federal Ministry of Food and Agriculture [BMEL], StBA, the Working Group on Energy Balances [AGEB], UBA, business associations in the field of renewables, and research institutes) is responsible for the field of renewables. The BMWi has recently tasked various independent academic institutes with producing energy projections and scenarios, including for renewables.

Policies and measures

Overview of policy framework, targets and objectives

The main policy measures and frameworks relevant to the deployment of renewables in Germany include specific policies supporting renewables deployment in the electricity, heat and transport sectors, as well as policies for energy efficiency – in particular in the buildings sector – and the more general energy and climate change policy framework.

The main changes in renewable support policies since the last in-depth review (IDR) include:

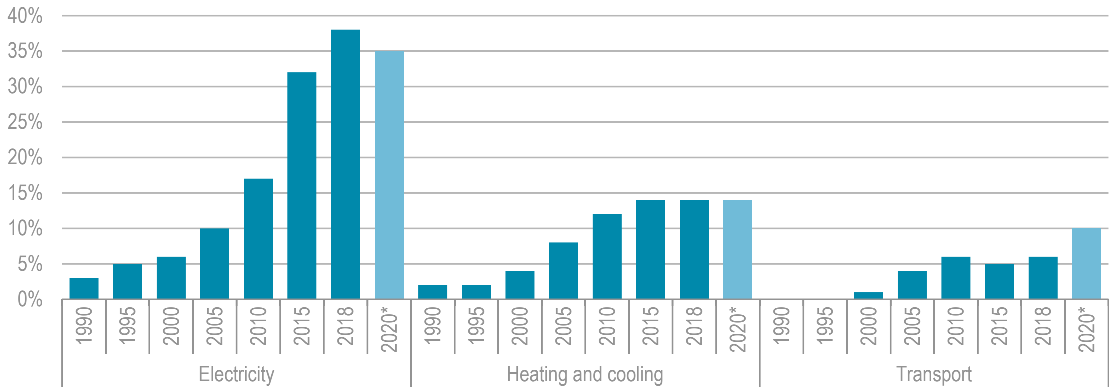
- Electricity: revisions of the EEG in 2014 and 2017, including the Offshore Wind Energy Act (Windenergie-auf-See-Gesetz), the Landlord-to-Tenant Electricity Act 2017, and the revision of the Renewable Energy Sources Act 2018 (Energiesammelgesetz).
- Heat: 2015 revision of the Market Incentive Programme (MAP); harmonised regulatory system for the heating market; promotion of heat pumps; low-temperature heat networks with seasonal thermal energy storage.
- Transport: GHG quota as an instrument for GHG emissions reduction in transport (Federal Immission Control Act, or BImSchG); measures regarding electric mobility/biofuels/rail transport.

Germany has a well-developed set of short-, mid- and long-term renewable energy targets and climate objectives stemming from its EU obligations as well as from national policies and legislation.

The EU Renewable Energy Directive 2009/28/EC (RED) supports a renewable energy target of 20% to 2020 and mandates Germany to achieve 18% of final energy consumption from renewables in electricity generation, heating and transport.

Since the adoption of the targets, Germany has achieved impressive progress in renewables, in particular in the electricity sector. In 2017, renewables' share in Germany's total final energy consumption stood at 15.5%. Germany already surpassed its renewables electricity generation indicative target in 2017 and the country is on track to reach its renewables heat target. However, the gap in the transport sector is significant (Figure 5.7). As a consequence, Germany is likely to miss its overall 2020 EU target of 18% renewables in TFC.

Figure 5.7 Progress towards 2020 targets



Germany has achieved impressive progress toward its renewables targets in the electricity sector, but less so in heating and cooling and transport.

* Target.

Source: BMWi (2019), "Development of renewable energy sources in Germany in the year 2018".

Germany has also set a number of longer-term targets, summarised in Table 5.1. The 2050 renewable target of 60% of renewables in total energy consumption and 80% of renewable electricity in power supply were adopted initially in 2010 via the Energy Concept and later transposed into law with the EEG 2012 reform.

Table 5.1 Targets and indicative trajectories of renewable energies in final energy consumption and electricity supply by year and policy

	Renewables in gross final consumption of energy*			Renewables in electricity supply				
	2020	2030	2050	2020	2025	2030	2035	2050
NREAP	18%			35%				
2010 Energy Concept			60%					80%
2018 Coalition Agreement						65%		
NECP draft		30%				50-52.5%		

* Target/indicative target for the share of energy from renewable sources in gross final consumption of energy.

Notes: NREAP = National Renewable Energy Action Plan; NECP = National Energy and Climate Plan.

Sources: Based on NREAP, 2010 Energy Concept, 2018 Coalition Agreement, NECP.

In March 2018, Germany adopted the Coalition Agreement, outlining a 65% target of renewables in final consumption to be achieved by 2030. This objective is complemented by renewable electricity targets included in the EEG that Germany's power supply will be mostly based on renewables by 2035 with shares ranging between 55% and 60%. In 2019, the government will decide on technology-specific expansion paths, complemented by corresponding grid infrastructure development plans.

A draft version of Germany's NECP was submitted to the European Commission at the end of 2018 indicating a target of 30% renewables in final energy consumption by 2030. According to the draft plan, by the same year, half of the country's power supply is to be generated by renewables.

Renewable electricity

The EEG is the pivotal policy instrument driving renewable electricity growth in Germany since its adoption in 2000. In its initial version, the EEG promoted renewable electricity production via guaranteed, long-term FiTs, kicking off renewables deployment in the country.

The act was substantially amended several times, including since the last IDR. The 2014 reform removed FiTs for utility-scale projects and required projects to use a direct marketing scheme for support. The reform also introduced capacity auctions as the price-finding mechanism for large-scale solar PV projects with pilot auctions rolled out in 2015 and 2016. The cross-border auction was tested in the same period in co-operation with Denmark per EU requirements.

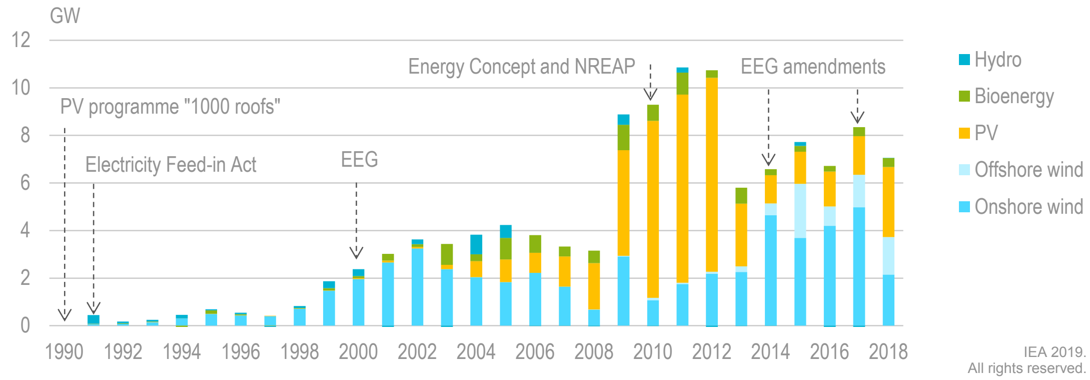
After successful results of the initial rounds, the EEG was further amended, requiring all systems greater than 750 kW seeking support to participate in competitive auctions starting in 2017. This marked a paradigm shift as competition became the main price-discovery mechanism for renewable electricity technologies, moving away from administratively set FiTs for the majority of renewable electricity deployment going forward. Today, beyond large-scale solar PV, onshore and offshore wind as well as biomass projects are required to compete in auctions in order to obtain power purchase agreements, awarded to the lowest bidder. Only hydropower, geothermal and small PV roof systems still have fixed FiTs.

The deployment of annual renewable capacity additions over time is illustrated in Figure 5.8, which also shows selected major amendments to legislation.

Oversimplifying a bit, the deployment of renewable capacities in Germany can be classified into three phases: 1) the early phase of FiTs, first fostering onshore wind then increasingly PV; 2) the years of the PV boom, when regulation struggled to cope with very fast technology cost reductions and rapid installation volumes, leading to a sizeable increase in the EEG surcharge; and 3) since 2014, the renewables deployment phase based on competitive auctions.

New capacity installations also depend on other factors aside from major legislation amendments. For instance, every announcement of a tariff reduction systematically brought boom and bust cycles, i.e. a rush of new installations before the deadline, followed by empty project pipelines in the following year. Other important factors are non-economic barriers, e.g. social acceptance and permitting issues, such as those currently impacting Germany's onshore wind sector.

Figure 5.8 Policy support changes and renewables capacity deployment, 1990-2017



Renewable power capacity deployment in Germany can be classified into three periods: the early phase, the PV boom phase and the more recent phase driven by competition.

Note: GW = gigawatts.

Source: IEA (2019b), *Renewables 2019.*

Focusing on the most recent competitive phase, the planned auction volumes include:

- For onshore wind 2 800 megawatts (MW) each year over 2017-20, followed by 2 900 MW per year.
- From 2017, operators of new, larger-scale PV installations with a capacity of more than 750 kW must participate in auctions. The volume is 600 MW per year. Small installations with a capacity of less than 750 kW are generally exempt from the obligation to take part in the auction process. In total, the targeted expansion rate is 2 500 MW each year.
- Additional auction volumes of 4 gigawatts each for onshore wind and solar PV, distributed over 2019-21 (1 GW in 2019, 1.4 GW in 2020 and 1.6 GW in 2021).
- Additional auctions addressing innovative solutions are foreseen; also distributed over a three-year period: 250 MW in 2019, 400 MW in 2020 and 500 MW in 2021.
- The first offshore wind auction was held in 2017. Planned annual new-build capacities are 500 MW for 2021-22, 700 MW for 2023-25 and 840 MW for 2026-30.
- In 2017-19, auctions of 150 MW of capacity each year and 200 MW a year from 2020-22 are planned for biomass installations. Existing biomass installations whose funding under the EEG is expiring can also participate in the auctions. This will give them the opportunity for ten years of follow-up funding.

Other relevant legislation includes:

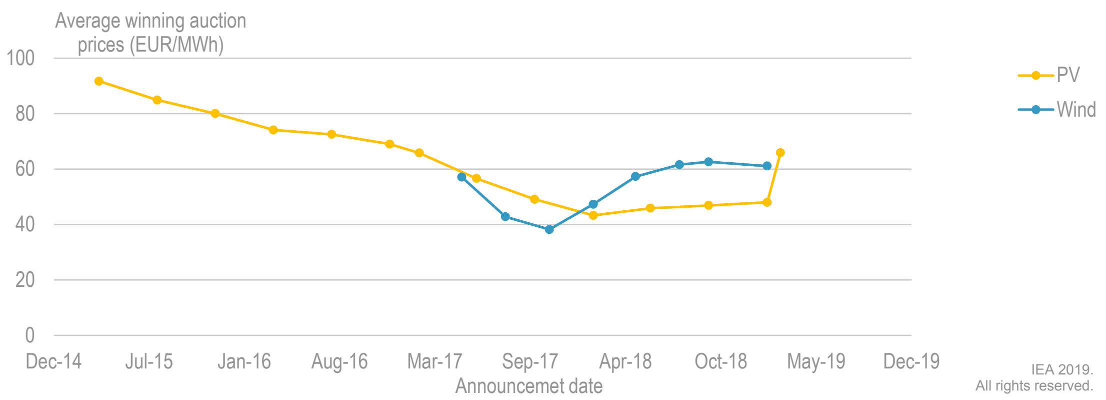
- The Offshore Wind Energy Act (WindSeeG) entered into force on 1 January 2017 as part of the 2017 EEG. The act stipulates that the level of funding for offshore wind power installations is also to be determined by competitive auctions. It additionally ensures dovetailing among site planning, regional planning, approval of installations, funding under the EEG and grid connection. This will improve the system and render it more cost-effective. The aim is to boost the installed capacity of offshore wind energy installations to a total of 15 GW between 2021 and 2030, following a set plan and in a cost-efficient manner.

- The Landlord-to-Tenant Electricity Act 2017 allows tenants to profit directly from the energy transition and creates new incentives for expanding solar energy generation in Germany. The goal of landlord-to-tenant electricity funding is to help tenants participate directly in the energy transition and to provide additional incentives for installing solar power on residential buildings.

Initial results from competitive auctions for wind and solar PV under the EEG revisions in 2014 and 2017 confirm that these reforms are important steps on the path to a successful and more cost-efficient energy transition. For the first time in 2017, total installed capacity of renewables (112 GW) surpassed that of fossil and nuclear combined (105 GW). The share of renewables in electricity generation increased from 25% in 2013 to nearly 38% in 2018. The success is particularly clear for solar PV, as average auction prices fell from around EUR 90 per megawatt-hour (MWh) in December 2014 to a record low of EUR 43.3/MWh in February 2018 (Figure 5.9).

The first auction for offshore wind was held in April 2017 for 1.5 GW, and four projects were selected. One project was awarded at EUR 60/MWh and the remaining three, totalling 1.4 GW, were awarded at EUR 0/MWh, i.e. a “zero” premium on wholesale market prices, signalling the increasing competitiveness of offshore wind. Similar results were observed in the second offshore wind auction held in April 2018 for 1.6 GW. Six projects were awarded at an average weighted price of EUR 46.6/MWh, with two projects bidding at EUR 0/MWh premium. Only existing projects for which there was remaining network capacity available after the first round could participate in the second round; 500 MW was earmarked for projects located in the Baltic Sea.

Figure 5.9 Price reductions in recent auctions for solar PV and onshore wind, 2014-19



Since 2014, competitive auctions in Germany have been effective at reducing average prices of renewables, in particular solar PV.

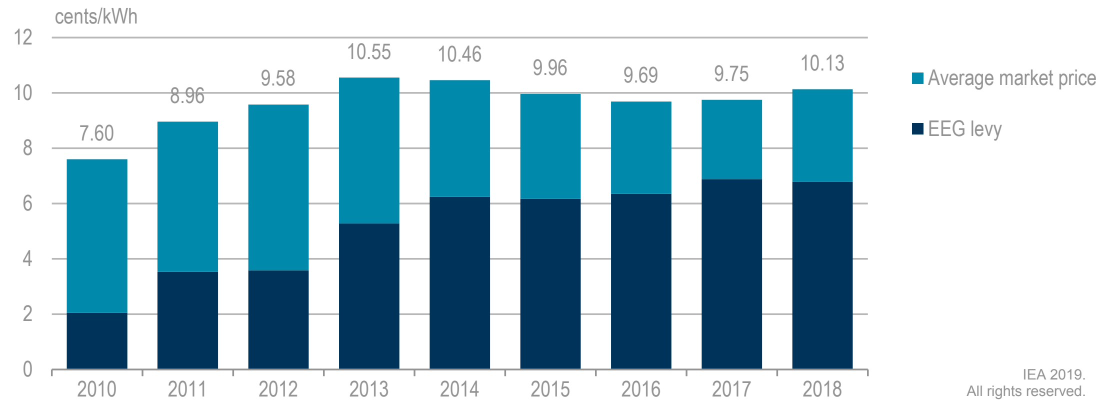
Sources: Bundesnetzagentur (2019a), “Ausschreibungen für EE- und KWK-An-la-gen” [Tenders for RES and CHP plants] and Bundesnetzagentur (2019b), “Be-en-de-te Ausschreibungen” [Closed Tenders].

The introduction at scale of competitive auctions and the recent policy changes have proven to be effective in stabilising EEG surcharges in the past few years (Figure 5.10), during which the generation of renewable electricity grew by 50%. The surcharge in 2018 was EUR 6.79 cents per kWh (kWh), i.e. slightly lower than in 2017.

Deployment of low/zero marginal cost renewables tends to reduce wholesale market prices. The sum of the EEG surcharge and the average wholesale price has remained relatively stable since 2013, which is an important signal for consumers (Figure 5.10).

Electricity prices in Germany include high taxes and levies, and the burden of the EEG is mainly on households, as large industries are largely exempt. Average household electricity prices in Germany stood at around USD 353/MWh in 2018, i.e. the second-highest across all IEA countries (see Chapter 7 on electricity). The total amount of the annual EEG surcharge was EUR 25.6 billion in 2018, a much higher level of support compared with the one for renewable heat (see next sections on renewable heat).

Figure 5.10 EEG surcharge and average wholesale electricity market price, 2010-18



Policy changes were effective at stabilising renewable energy surcharges since 2014. The sum of the market price and EEG surcharge was lower in 2018 than in 2013.

Source: BMWi (2019), "Development of renewable energy sources in Germany in the year 2018".

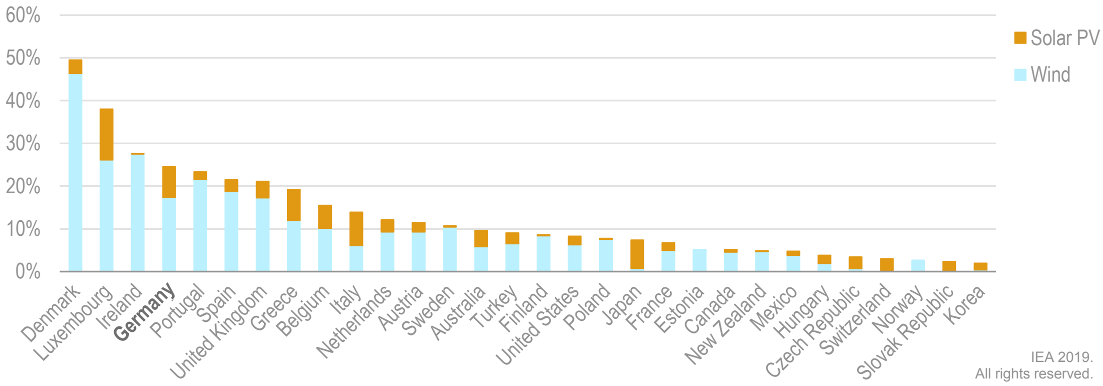
System integration of variable renewables

The sum of wind and solar shares in Germany was 25% in 2018. This is the fourth-highest share across IEA countries, close to the level of Ireland (Figure 5.11). Such high shares of variable renewables require large flexibility resources.

Flexibility in the German power system is mainly provided by conventional thermal capacities, notably gas power plants, but also by hard coal power plants (Figure 5.12). This is complemented by hydropower pumped storage systems. Going forward, taking into account the planned phase-out of nuclear in 2022 and the planned progressive phase-out of coal by 2038, the flexibility requirements of an increasing share of variable renewables will need to be carefully monitored and reassessed (see also next section on prospects of renewables).

The aim for Germany is to source 40-45% of its electricity from renewable sources by 2025, as established in the EEG. According to the coalition agreement, the federal government is planning to increase the share of renewable energy in the electricity sector to 65% by 2030. This will require the continued expansion of renewable energy use in a way that is ambitious, efficient, better synchronised with grid development and increasingly market-oriented.

Figure 5.11 Share of solar and wind in electricity generation in IEA countries, 2018

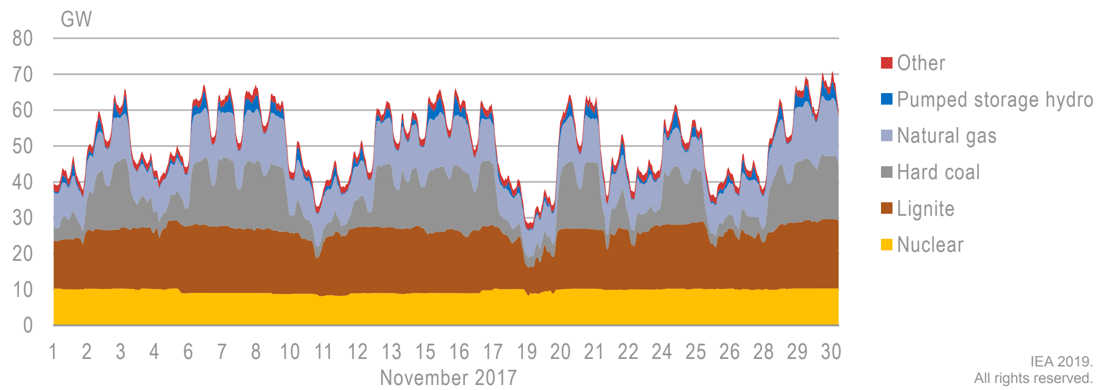


Germany has the fourth-highest share of variable renewables in electricity generation in the IEA.

Notes: For Luxembourg, domestic electricity generation only covers a small part of demand (most is imported). Data are provisional.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/

Figure 5.12 Conventional electricity generation in Germany, November 2017



In Germany, increased power plant flexibility has allowed for greater variable renewables integration as well as allowed conventional power plants to remain in the market.

Source: IEA (2018b), Status of Power System Transformation.

In the context of the Grid Development Plan for 2019-30, a review is under way on transmission grid measures necessary to accommodate the growing shares of variable renewables. By the autumn of 2019, the coalition parties will decide on the technology-specific expansion paths needed for this, up to the year 2030. Where applicable, adaptations may need to be made to auction amounts to reach the 65% objective.

Today, the biggest issue in terms of integration are congestion issues, due to the fact that the vast majority of wind installations are in the north, while strong electricity demand from industry comes from the south and the west. This calls for strong grid reinforcements, which were planned a while ago but are significantly lagging behind plans (for a more detailed discussion, see Chapter 7 on electricity). Reinforcement and new construction of power lines will bring benefits in terms of increasing flexibility, reducing curtailment and enabling a more secure and cost-effective deployment of wind and solar.

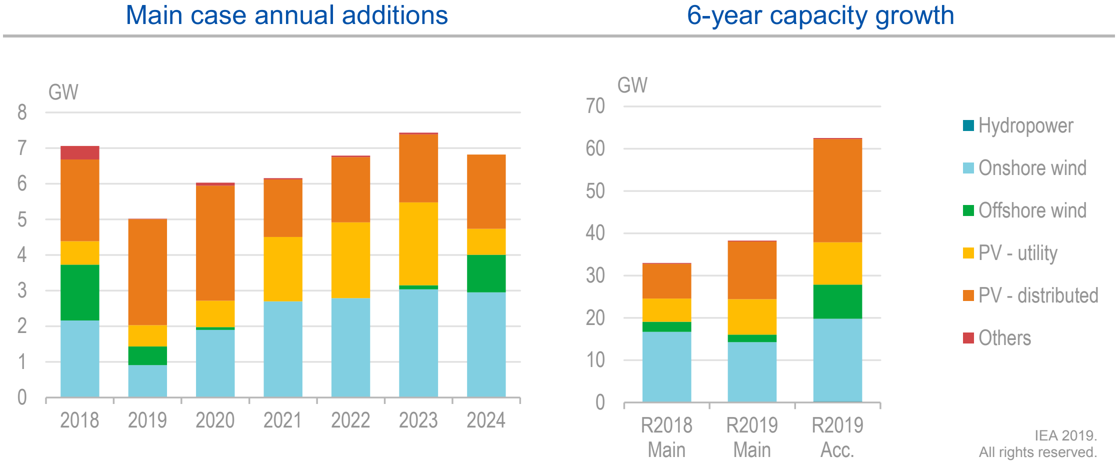
Forecasts for renewable electricity

Based on the analysis of the electricity market and of the policy framework in Germany, the IEA forecasts that renewable electricity capacity will increase by 30% by 2024 in the main forecast case (Figure 5.13). The overall growth (35 GW) is similar to the growth experienced over the last six-year period (2013-18), though with lower financial support, given the cost reductions achieved by competitive auctions.

Solar PV is expected to lead the capacity growth – almost evenly split between utility-scale systems and distributed systems. Competitive auctions are the main driver of utility-scale growth while increasing economic attractiveness of self-consumption for commercial systems is the main driver for distributed PV growth.

In 2018, annual growth of commercial scale PV systems increased 25% due to an improved business case for self-consumption driven by falling module costs, high retail tariffs and remuneration for excess generation above wholesale electricity prices. This trend is expected to continue to drive growth of the commercial segment over the next six years. However, for residential systems, the attractiveness is more uncertain. Residential systems still have access to fixed FiTs, and the business case for self-consumption will depend on the evolution of retail prices, system costs and remuneration levels.

Figure 5.13 IEA forecast of renewable capacity additions in Germany, 2018-24



German renewable capacity is forecast to grow by 30-60% by 2024, depending on policies implemented in the next 24 months.

Note: Acc. = IEA Accelerated Case.

Source: IEA (2019b), *Renewables 2019*.

Onshore wind is the second-largest source of capacity growth over the forecast period and a result of competitive auctions. However, annual growth is expected to be volatile, particularly in 2019, based on a lull in the project pipeline due to the long lead times resulting from specific conditions for pilot auctions held in 2017. The first three auctions in 2017 allowed co-operative wind parks to bid without permits and as much as 54 months to commission projects. New onshore wind installations are also suffering from mounting social resistance and lengthy permitting issues.

Offshore wind capacity is expected to increase by 25%, from projects currently under construction and in advanced stages of development.

Based on these trends, the IEA estimates that renewable electricity will increase to 300 TWh by 2024. Should the pace of deployment be maintained to 2030, renewable electricity generation could reach over 360 TWh. The IEA estimates that this trend would put the share of renewable generation on a path to exceed 50% by 2030, based on current plans for nuclear and coal phase-outs over the same period.

Higher shares of renewable electricity generation are possible by 2030, as assumed in IEA's Accelerated Case. Overall renewable capacity growth in Germany could be two-thirds higher – reaching almost 60 additional GW – with increased policy certainty for solar PV and fewer administrative challenges for permitting of onshore wind.

For solar PV, one of the main challenges is policy uncertainty from 2020 onwards. For utility-scale systems, the auction schedule beyond 2021 is unknown, while for distributed PV growth there is no clarity whether remuneration above market prices of electricity exported to the grid will be extended beyond the 52 GW cumulative installed capacity cap. If remuneration is not changed, growth could be 50% higher over the next five years.

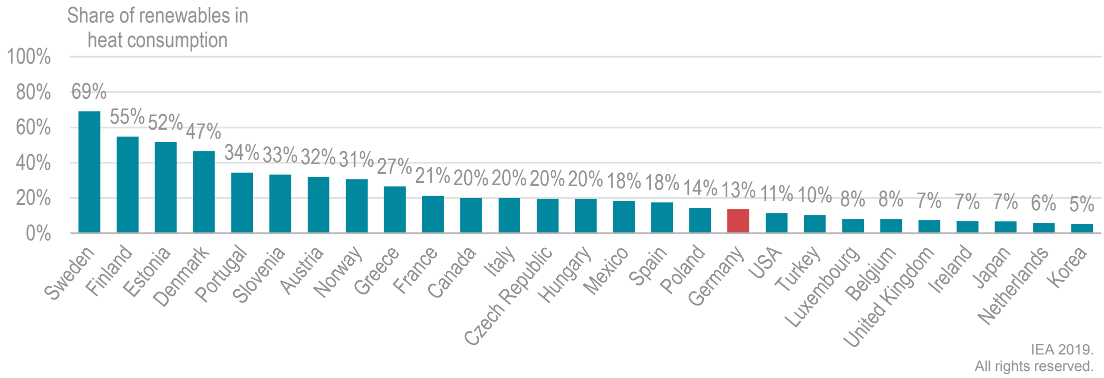
Two of the main challenges for higher onshore wind growth are lengthy permitting times and the impact of decommissioning/repowering older turbines. Tighter state-level permitting requirements, less availability of regional development zones, and increased legal challenges stemming from local opposition have led to longer permitting times; now up to two years (WindEurope, 2019). In addition, the pace of decommissioning of older plants, which averaged 300 MW per year over 2013-18, could also challenge growth. Over the next six years, more than 10 GW of capacity will reach the end of its support lifetime, which can prompt developers to decide whether to dismantle, enter into the wholesale market or repower their plants and compete for support with new-build projects in auctions. Measures to decrease the permitting procedures times, solve the grid constraints and increase the business case for repowering could result in over 40% more onshore wind growth by 2024.

Renewable heat

Heating (and cooling) in Germany accounts for over 50% of total final energy consumption and around 40% of carbon dioxide (CO_2) emissions. The German heating sector is still heavily dependent on fossil fuels, supplying more than 80% of direct heat in the residential sector. Of particular note, 25% of heating is fuelled by heating oil. The share of renewables is limited (14%) in district heating, which supplies 10% of heat demand in residential and commercial buildings.

Overall, the share of renewable energy in heating and cooling was 14.2% in 2018. While this number meets Germany's renewable heat target for 2020 of 14%, it is much lower than the renewable heat share in many other IEA countries, especially in Europe (Figure 5.14).

Figure 5.14 Share of renewable energy sources in heating and cooling, IEA countries, 2017



The share of renewable heat in Germany is close to the relevant 2020 EU RED target, but is significantly lower than in many other IEA countries.

Sources: Eurostat (2019), SHARES 2017 detailed results for EU countries; IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/; IEA (2019d), *World Energy Outlook 2019* for non-EU countries.

A major instrument for promoting renewable heating/cooling is the Renewable Energy Heat Act (EEWärmeG), in addition to the MAP, which provides an additional source of funding for these areas. Other relevant policies in the building sector include the Energy Conservation Act (EnEG), the Energy Savings Ordinance (EnEV) and the more general decarbonisation strategy. While this legislation has brought progress, particularly for new buildings, Germany will need much stronger policy efforts to reach the 30% target for renewable heat in its 2030 NECP. While a mobility commission was set up to draw a plan for decarbonising the transport sector, heating (and cooling) remains a sector in which the government is still in the process of formulating a sectoral plan for emissions reductions.

Direct renewable heat

Renewable energy in heating (and cooling) can be supplied directly or indirectly. Direct use is dominated by bioenergy – either in the form of solid biomass fuels or biogas fed into gas networks. Other sources of renewable heat include geothermal and solar thermal, which collectively accounted for roughly 13% of total renewable heat in 2018. Looking at the historical trend, direct final consumption of renewable heat almost tripled between 2000 and 2010 but has basically stalled since then. The share of renewable heat has been narrowly fluctuating in recent years (Figure 5.5).

The main policy instrument supporting direct renewable heat in Germany is the EEWärmeG, which entered into force on 1 January 2009 and has since been repeatedly amended. The act is intended to help raise the share of renewables in energy consumption for heating and cooling to 14% by 2020. It stipulates that new buildings are required to have a percentage of their heating requirements met with renewable energy sources. The act also addresses public buildings to be renovated. Certain compensatory measures, such as additional insulation and the use of co-generation[9] systems or district heating, are also addressed.

[9] *Co-generation* refers to the combined production of heat and power.

The federal government has to report every four years on experience with the act and to submit proposals on its further development. The second Progress Report was published in November 2015. So far, the EEWärmeG has been considered effective in achieving the EU 2020 target, with specific reference to new buildings. For instance, the share of oil heating systems in new buildings has decreased from 10% in 2004 to 0.7% in 2016. However, yearly renovations in Germany occur in only around 250 000 buildings, or 0.5%. Going forward, it is clear that new and additional policy instruments will be needed, addressing the entire building stock of around 51 million units.

The MAP is an additional and complementary support scheme intended to help reach the 14% goal of the EEWärmeG by 2020. It aims at further expanding the deployment of technologies to use renewable energy in the heating/cooling sector, such as solar thermal installations, wood pellet heating systems, and efficient heat pumps.

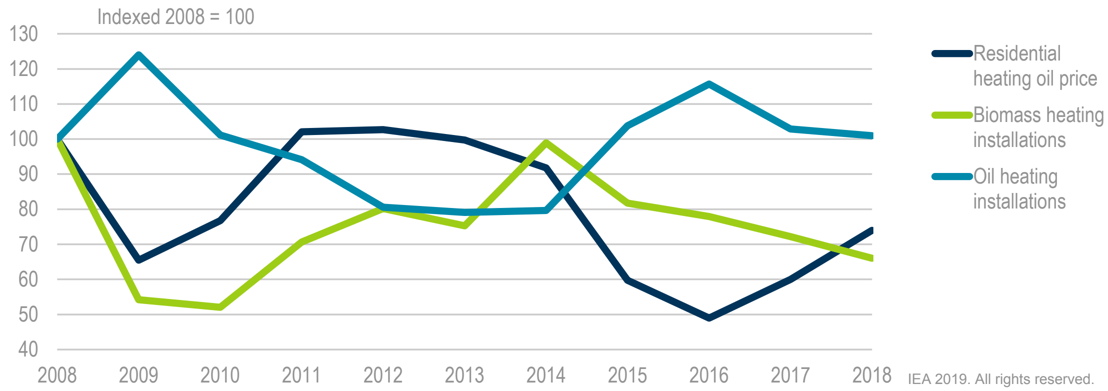
The MAP provides two kinds of support, depending on the type and size of the installation. For small installations, primarily in existing buildings, investment grants are issued through BAFA. Applications for such funding mainly come from private investors in single-family or two-family homes. For larger installations, as well as for heat networks and storage, repayment grants are offered in the form of low-interest loans under the KfW Renewable Energies Programme, mainly to commercial or local government entities.

The annual budget is approximately EUR 320 million. In 2017, the MAP for Renewable Energy in the Heating Market supported the installation of approximately 70 000 renewable energy heating systems – most of them in residential buildings – for a total volume of grants of about EUR 200 million and a corresponding investment level of nearly EUR 900 million.

While the MAP has certainly been beneficial to the deployment of renewable heat technologies, in the absence of stronger interventions (e.g. a carbon price and/or taxation reforms), the most important determinant influencing private investment remains the price of oil. IEA analysis shows that there is a clear correlation between residential heating oil prices, which vary with crude oil prices, and market trends in heating system installations. From 2008-18, during periods of high heating oil costs, the number of new oil boiler installations reduced, while biomass heating systems grew. The opposite is generally observed at times of lower oil prices (Figure 5.15).

Last but not least, renewable heat technologies are eligible for financial support under the CO_2 Building Rehabilitation Programme, which provides financial incentives for energy-efficient and clean energy renovations. The programme’s 2017 budget was EUR 2 billion, the bulk of which was used for low-interest loans; around 400 000 buildings received funding in 2017. Germany does not provide financial incentives in the form of tax breaks to households or businesses for upgrading heating systems (see also Chapter 3 on energy and climate change).

Figure 5.15 Biomass versus oil heating in new installations in Germany, 2008-18



Heating fuel oil prices are the key parameter determining sales of biomass versus oil heating installations.

Sources: IEA (2019c), Energy Prices and Taxes First Quarter 2019; BDH (2019) Marktentwicklung Wärmeerzeuger 2008-2018 [Market Development of Heating 2008-2018].

In line with Germany's dual strategy for decarbonisation of the heating sector, which aims to maximise energy efficiency gains while simultaneously increasing the role of renewables, policies are aligned accordingly. Energy-saving requirements for buildings are set out in the EEWärmeG, EnEG and EnEV.

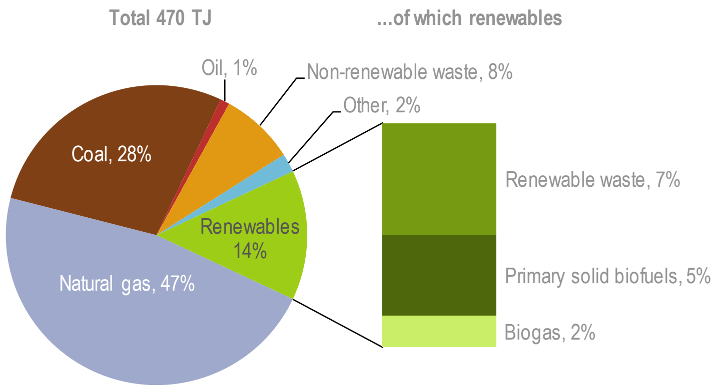
Going forward, the energy conservation law for buildings will be simplified and streamlined during the current legislative term. The regulations of the EnEV, EnEG and EEWärmeG will be merged into a new Act on Energy in Buildings, thereby transposing the requirements of EU law for public non-residential buildings with effect from 1 January 2019 and for all buildings with effect from 1 January 2021. The current energy-related requirements for existing buildings and new buildings will continue to apply.

District heating

District heating accounts for only around 8% of total residential energy demand in Germany. While this is a relatively minor level compared with several other European countries, the share is increasing thanks to developments in urban areas. More than 20% of new apartments are connected to district heating. District heating is considered for its potential to integrate renewable heat and contribute to sector coupling. As shown in Figure 5.16, however, fossil fuels dominate district heat production, with renewables (essentially bioenergy and waste) representing only 14.4% in 2017, i.e. half of coal (28%). (See also Chapter 3 on energy and climate change for a more detailed discussion on district heating and co-generation.)

The funding programme Heat Networks 4.0 (Modellvorhaben Wärmenetzsysteme 4.0) was implemented on 1 July 2017, to incentivise the planning and implementation of modern, high-efficiency networks with high shares (>50%) of renewable energy and waste heat supply. The rate of funding under this scheme depends on the share of renewables and waste heat in the network (it increases for each additional percentage point in renewables share), and applies to the entire network system (including heat production, distribution and storage infrastructures).

Figure 5.16 Fuel shares in district heating in Germany, 2017



District heating is expanding, particularly in new buildings, but energy supply is still dominated by fossil fuels.

Note: TJ = terajoule.

In principle, district heating could provide a short-term opportunity for fuel switching (in particular from coal) and scale up the use of renewables, especially of biomass and waste. This successfully occurred in Slovakia, Denmark and other Nordic countries, triggered by taxes on carbon and on fossil fuels. Exploiting scale effects, it is easier, faster and more cost-effective to intervene on centralised heat generators than replace multiple individual boilers in buildings. Business stakeholders make investment decisions, and fuel switching does not represent any disruption in usage for households and consumers.

In practice, however, supporting a larger role for renewables in district heating would require decreasing the operating temperature of networks, which are currently running at relatively high temperatures (100°C to 120°C). As such, a shift to renewables would need to be complemented by strong improvements in energy efficiency, including stricter insulation measures.

Electric heating and sector coupling

While an official strategy for the decarbonisation of heating and cooling has not been published yet, the government considers sector coupling, i.e. using efficient electric heating devices, as a central instrument for decarbonising heating (and cooling) in buildings and industry.

Heat pumps offer a valuable route for sector coupling, as well as CO_2 emissions reduction from the displacement of fossil heating fuels. For example, an electrically driven heat pump with a seasonal performance factor (SPF)[10] of 3.5 emits around 155 grammes of CO_2 per kWh of heat, given the current carbon intensity of Germany's electricity generation. By comparison, emissions from a natural gas boiler are around 50% higher, and 65% higher for an oil heating boiler. With the increasing share of renewables in Germany's electricity generation and planned phase-out of coal

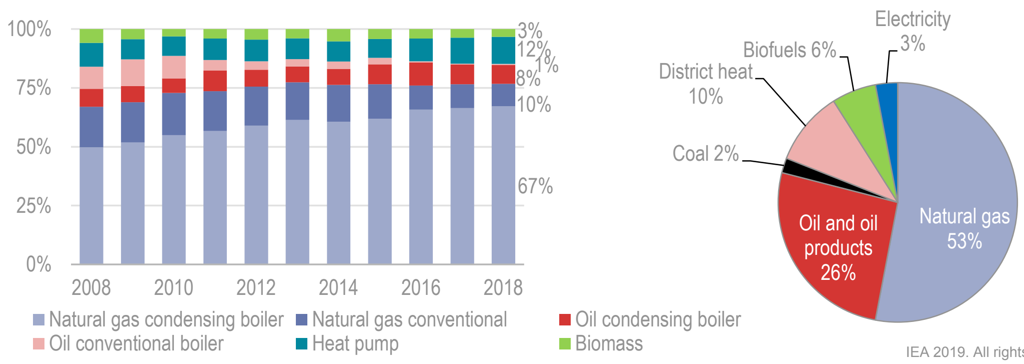
[10] SPF = the average efficiency of a heat pump over a heating season.

generation (see Chapter 7 on electricity), the potential of heat pumps to decrease buildings CO_2 emissions will increase substantially over the long term.

According to European Heat Pump Association data, the number of cumulatively installed heat pumps in Germany tripled from 350 000 in 2008 to one million in 2018. This growth in installations has been supported via investment support from the MAP for building renovations, and the Energy Efficiency Incentive Program (APEE). With a 12% market share, since 2017, heat pumps have overtaken oil boilers to become the second-highest-selling heating system after gas boilers. This is also the consequence of the EEWärmeG, stipulating that construction of new buildings will be permitted only if they use renewable sources for space and water heating. Since January 2016, oil burners are no longer permitted as a means of heating in new buildings.

While these are all positive trends, they concern only a minority of buildings and installations. Taking into account the whole building stock, both sales and cumulative installations were still dominated by fossil fuels in 2018. Gas boilers accounted for more than three-quarters of total sales, while oil condensing boilers (allowed only in old buildings) represented 8% of the market (Figure 5.17). Most importantly, in cumulative terms, heat pumps still represent only 2.5% of energy consumption for heating and cooling, while fuel oil heating supplies more than 25% of the total. A major reason for this situation is the different taxation regime for different fuels for heating.

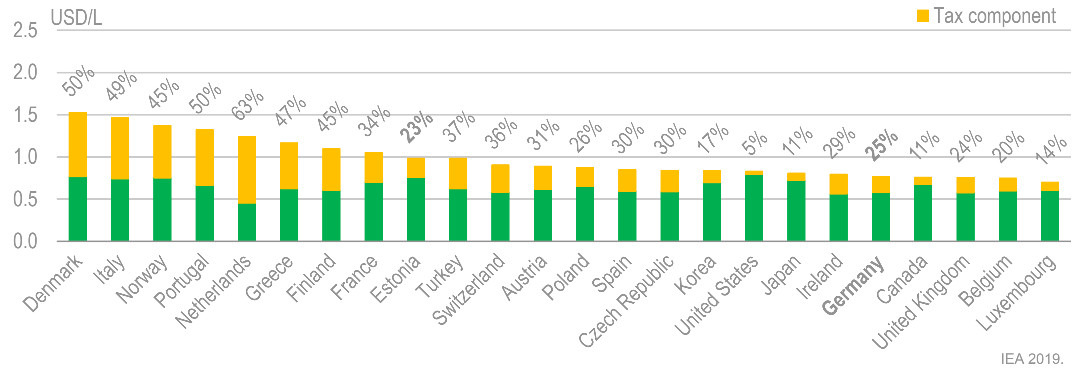
Figure 5.17 Fuel shares in sales and energy consumption for residential space heating in Germany



Source: BDH (2019) *Marktentwicklung Wärmeerzeuger 2008-2018* [Heating Market Developments 2008-2018].

As of January 2019, statutory tax rates in Germany were EUR 61.35/1 000 litres (L) (~EUR 5.3/MWh) for heating oil and EUR 5.50/MWh for natural gas, compared with EUR 20.50/MWh for electricity. These levels have not significantly evolved since the last IDR. This positions Germany as the country with one of the lowest heating oil prices among all IEA countries (Figure 5.18).

Figure 5.18 Heat oil fuel prices in IEA in Q1 2019



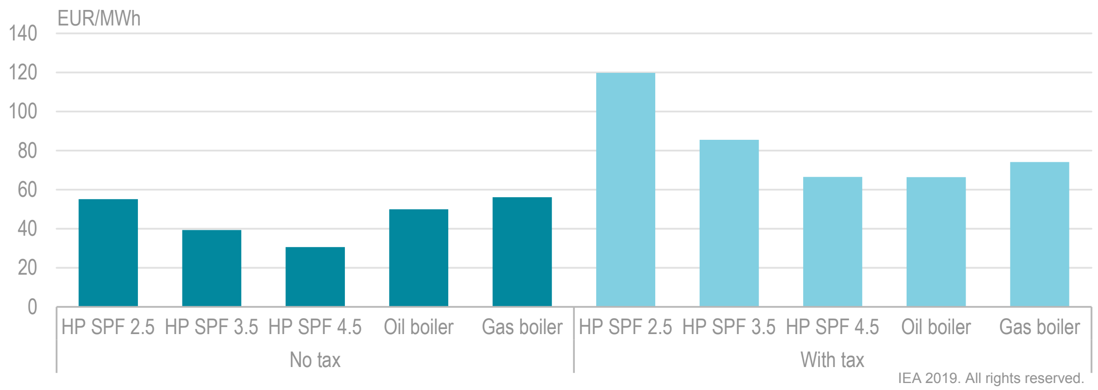
Germany has one of the lowest price and a low taxation rate for heating oil fuel among IEA countries. This is a strong barrier against renewable heat and sector coupling.

Source: IEA (2019c), *Energy Prices and Taxes First Quarter 2019*, www.iea.org/statistics/.

Even considering the higher efficiency of heat pumps, the current taxation regime acts as a significant barrier to sector coupling in the heating sector in Germany. Figure 5.19 compares the different operating costs for households for different heating appliances, including heat pumps with different SPF levels.

While the fuel costs (excluding tax) associated with heat pumps with a SPF of 3.5 or higher are lower than oil boiler and gas boiler costs, the higher taxation on electricity relative to heating oil and natural gas results in total fuel costs above oil and gas boilers for all but the most efficient heat pump systems. Most importantly, heat pumps with an SPF of 2.5, indicative of an air-water heat pump, have far higher running costs when taxation is factored in. This particularly affects air source heat pumps in colder climates, which have wider building suitability than more efficient ground source heat pumps.

Figure 5.19 Household delivered heat costs for different heating appliances, 2018



Low heating oil taxation in Germany creates an economic barrier to the adoption of all but the most efficient heat pump systems, challenging sector-coupling opportunities.

Notes: HP = heat pump. Assumed efficiency of oil boiler 93%, assumed efficiency of natural gas boiler 88%. Domestic heating oil prices correlate closely to crude oil price and are therefore variable over time.
Source: IEA (2019a), *Energy Prices and Taxes*, www.iea.org/statistics/.

In the context of heat, it is also important to note that the APEE may lead to an unintended consequence of locking-in fossil fuel consumption for heating, as it also provides financial support to upgrades from older oil and gas boilers to newer boilers.

Prospects for renewable heat

In the draft NECP submitted to the European Commission at the end of 2018, Germany proposed a 27% target for the share of renewables in heating and cooling in 2030, with a 24-32% range for the buildings sector. However, according to the baseline scenario discussed in the NECP, renewable energy would account for only 17.3% of the heat consumption in 2030 – well below the indicative target – if current policies were to remain unchanged.

While current policies have brought progress in renewable heat, much stronger efforts are needed to achieve the necessary step change in the pace of renewable heat technology deployment to achieve Germany's ambitious 2030 targets. This includes removing the tax advantage for fossil fuels as discussed above, and significantly increasing financial support. For comparison, the total amount of incentives in the buildings sector in 2018 was around EUR 2.5 billion per year, which is only 10% of the amount German consumers pay annually for the EEG surcharge.

Changing the existing distortions across taxation of different fuels for heating and cooling will be necessary if Germany effectively wants to implement sector coupling at scale in buildings and industry. At the same time, Germany may consider introducing a carbon tax or a carbon price, which have proven to be effective instruments in Nordic countries, for triggering a fuel shift towards low-carbon sources of energy for heating and cooling. In addition, tax breaks for building renovations have proven to be an effective and cost-efficient instrument to foster both energy efficiency and renewables in existing buildings in other European countries, most notably Italy.

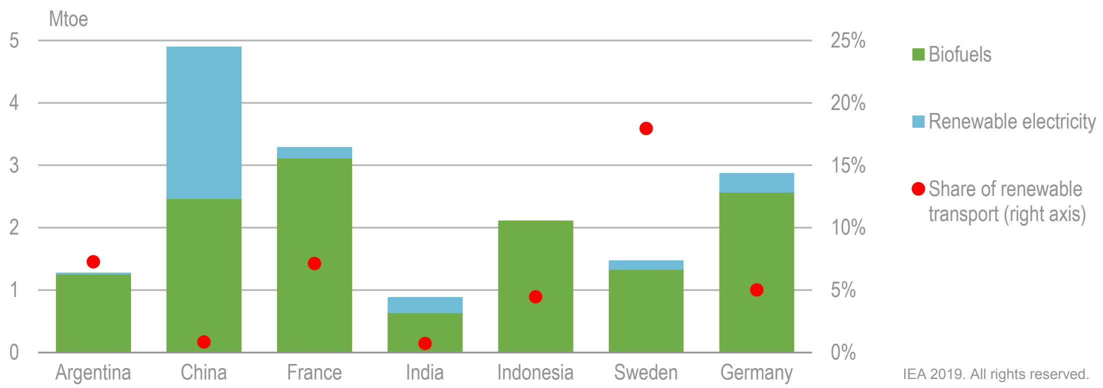
Renewable transport

Transport accounted for 25% of TFC in Germany in 2017 and 22% of energy-related CO_2 emissions. However, the sector has proven to be the most challenging to deliver GHG emissions reduction, not only in Germany. Transport has a lower share of renewable energy consumption than electricity and heat.

Biofuels account for most renewable energy in transport in Germany. However, similar to many other countries, Germany's share of renewables in transport is relatively low at around 5% (Figure 5.22). This is because most biofuels are currently consumed through blending at low percentages (typically 10% or less by volume or energy) with fossil fuels.

In 2015, Germany switched from a 6.25% energy-based biofuels mandate to the climate protection quota (CPQ) policy. This places annual GHG emissions reduction targets on transport fuel suppliers. The CPQ was initially set to deliver a 3.5% reduction, before increasing to 4% in 2017. Biofuels, electricity and upstream efficiency savings can be used for compliance under the policy. Tax incentives for biofuels expired on 1 January 2016, leaving the CPQ as the sole means of biofuel policy support. The introduction of the CPQ provides a direct mechanism to meet the requirement of the EU Fuel Quality Directive that fuel suppliers reduce the GHG emission intensity of automotive fuels marketed in 2020 by 6% compared with 2010 levels. The CPQ has stimulated annual increases in the emissions reduction (relative to fossil fuels) offered by the biofuels used for compliance (Figure 5.21). This is because under the CPQ, biofuels produced from waste and residues, which can offer significant levels of GHG reduction for a given volume, are attractive for compliance purposes. In 2017, the average GHG reduction from all biofuels used for compliance versus gasoline was over 80%.

Fig 5.20 Renewable energy in transport by source in selected countries, 2016



Germany, like many other countries, has a low share of renewable energy in transport, falling short of EU targets.

Source: IEA (2018a), *Renewables 2018*.

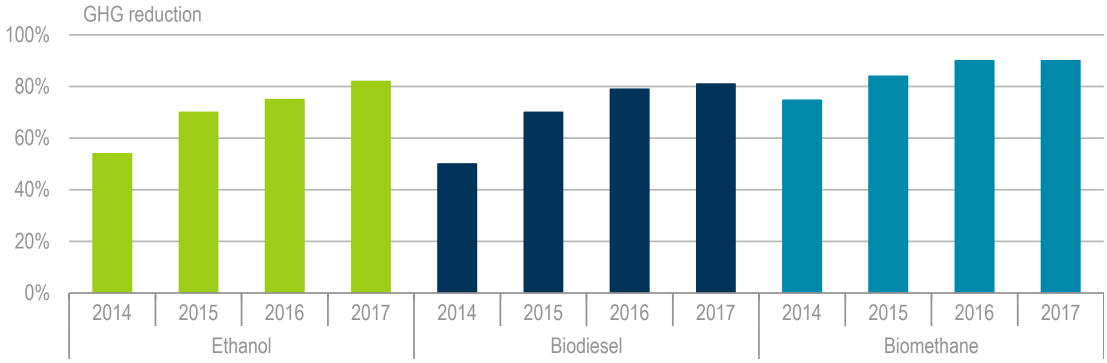
Nevertheless the current (4%) CPQ target level has not stimulated an increase in ethanol or biodiesel consumption volumes. These have fallen relative to consumption under the mandate, and in energy terms are below 2012 levels. The GHG emissions reduction required in the CPQ is set to increase to 6% in 2020. However, in the context of increasing transport energy demand and electric mobility from a low base, it is unlikely that this will be sufficient to ensure that the EU RED 10% target for 2020 will be met. Even taking into account the double-counting rules, Germany's share of renewable transport was just 7% in 2017.[11]

The updated RED for the 2021-30 period requires a 14% share of renewable energy in transport, comprising a maximum share of conventional crop-based biofuels of 7%. The CPQ is anticipated to be the key policy mechanism used to meet this target. Germany's draft NECP outlines that it will comply with the 14% target but will limit consumption of conventional biofuels to current levels (5.3%). As such, consumption of conventional biodiesel and ethanol in Germany is anticipated to stabilise and potentially decrease slightly due to the increasing efficiency of the European vehicle fleet.

In 2017, just over a fifth of biofuels consumption was supplied domestically. The draft NECP commits to meeting the 3.5% sub-target for advanced biofuels (including double-counting, corresponding to 1.75% in energy terms) required by 2030. Therefore, there is a clear role for policies to facilitate innovation, technology learning and a production scale-up of advanced biofuels necessary to reduce costs and increase consumption. Relevant policies include advanced biofuel quotas and financial de-risking measures, such as loan guarantees from development banks. Technically mature biofuels produced from used cooking oil and animal fats can separately contribute up to 3.4% (includes double counting, 1.7% in energy terms, more details in the final NECP).

[11] Under the EU RED methodology, renewable electricity and certain biofuels from waste and residues are eligible for double-counting against the EU target.

Figure 5.21 GHG emissions reductions from biofuels used for CPQ compliance 2014-17, compared with gasoline and diesel



The German CPQ has been effective in improving GHG emissions reductions per litre of all forms of biofuels compared with fossil transport fuels.

Notes: In 2014, a 6.25% energy-based mandate was in place; over 2015-16 the CPQ was in place with 3.5% GHG emission reduction target, increasing in 2017 to a 4% GHG emission reduction target.

Source: F.O. Licht (2018), "Germany – Biofuels' GHG savings rise to over 80%".

Increased uptake of electric mobility is also likely to be needed if Germany's 2030 target is to be achieved. Electricity used in road transport is eligible to be multiplied fourfold. The government targets 1 million electric vehicles (EVs) by 2020 and 6 million by 2030 (BMU, 2019). Recently, an aspirational target of 10 million EVs by 2030 was mentioned.

The increasing penetration of renewable energy in Germany's electricity generation portfolio, reaching 36% in 2018, has supported a 17% reduction in the carbon intensity of electricity supply, from 490 tonnes of CO_2 (tCO_2) per MWh in 2008 to just over 400 tCO_2/MWh in 2018. The continuation of this trend, alongside the higher efficiency of electric motors compared with internal combustion engines, supports the potential for EVs to contribute towards Germany's renewable energy and emissions reduction policy commitments for 2030 and beyond (see Chapter 4 on energy efficiency).

Germany's draft NECP acknowledges that the European Union's minimum requirements for conventional biofuels and new renewable technologies will not be enough to meet Germany's energy and climate goals. Germany is also at the forefront of the development of synthetic fuels produced from renewable electricity, CO_2 and water via power-to-liquid processes that may offer an alternative fuel source for transportation in the long term.

Assessment

Renewables have made significant progress in Germany in recent years, driven by robust policy support underpinning a strong increase in renewable electricity. For the first time in 2017, the total installed capacity of renewables (112 GW) surpassed that of fossil fuels and nuclear combined (105 GW). The share of renewables in electricity generation increased from 25% in 2013 to nearly 38% in 2018.

At the same time, significant progress was achieved in limiting the costs of the EEG surcharge, in line with the IDR 2013 recommendation. Owing to reforms in 2014 and 2017, the EEG surcharge remained relatively stable from 2014 to 2018, while the amount of renewable electricity increased by 50%. The IEA commends these trends, as well as the government's commitment to accelerate progress in grid planning and construction.

However, so far the energy transition has mostly been limited to the electricity sector. The vast majority of transition costs have been covered by electricity consumers, in particular households, due to large exemptions enjoyed by substantial parts of industry. Moreover, electricity only accounts for less than a quarter of total final energy consumption. Consequently, strong progress in renewable electricity has not been enough and Germany is likely to miss its 2020 renewable target. Final heat generation based on renewable energy sources in 2017 was slightly lower than in 2012, while the consumption of renewable energy sources in the transport sector has remained basically stable since 2009. In line with 2013 IDR recommendations, going forward it is crucial that both the costs and benefits of the transition are more equitably distributed across energy sectors and stakeholder groups.

Looking ahead, much stronger effort will be needed for heating and cooling in building and industry and in transport to achieve the 30% target share of renewables in TFC by 2030 as indicated in the draft NECP and in line with long-term 2050 objectives. Accelerating progress in energy efficiency will be critical for achieving a higher renewable energy share. The IEA commends the government's approach prioritising energy efficiency first, then exploring cost-effective renewable heat options and finally promoting sector coupling, as well as the recent dialogue on the role of gas in the energy transition. The government should work in close collaboration with industry to elaborate roadmaps and measures to support innovation and competition across renewable fuels, including biogas, advanced biofuels, renewable-based hydrogen, and synthetic fuels and feedstocks.

Renewable heat faces several barriers, reflecting the complexity of the sector. According to the draft NECP, the share of renewable heat needs to double from 14% to 27% by 2030. Achieving this ambitious target will require sub-sector strategies for different end uses in buildings and industry. Today, renewables supply only 6% of residential heat, as opposed to 26% from heating oil. Several policy instruments supporting renewables in buildings are in place, but their ambition needs to be significantly strengthened. For instance, the total amount of financial incentives is around EUR 2.5 billion per year, i.e. ten times less than the annual EEG surcharges. Moreover, most support measures focus on new buildings, but those represent only 0.5% of the total building stock. A number of options could be considered to accelerate renewable heat expansion, including tax deductions for deep renovations, a carbon price on sectors that are not part of the EU Emissions Trading System, redistributing revenues to incentivise energy efficiency and renewables, and imposing quota obligations.

The share of renewables in final energy consumption for transport in 2017 was only 5.2% in energy terms – the same value as in 2016. Even taking into account double-counting rules for EVs, which increase the share to 7%, the latter is well below the mandatory target of 10% by 2020 of the European RED. The draft NECP states that the federal government will implement the minimum requirements of the new RED – at least 14% by 2030 (mandatory target, double-counting permitted) – i.e. a tripling of the share in energy terms in the next 11 years. This target is to be achieved through, among other things, stricter GHG reduction quotas, to be fulfilled by companies placing transport fuels on the market.

Currently the quota is 4% and will increase to 6% in 2020. Biofuels, renewable electricity and upstream emissions reductions are all eligible for reaching the quota. A holistic strategy considering EVs for urban mobility and other options such as biofuels or synthetic fuels for long-haul transportation will be needed.

In 2017, renewable electricity accounted for only 0.7% of final energy consumption in transport, but recently new momentum has emerged from the German car industry. Informal targets currently under discussion are 1 million EVs by 2022, 6 million by 2025 and 10 million by 2030. Reaching these ambitious targets will require a massive effort including in planning smart charging infrastructure and managing the possible impacts on distribution grids.

Sector coupling can, in principle, play a very important role in the energy transition. The use of renewable electricity for transport with EVs and for heating and cooling in buildings and industry – e.g. with heat pumps – can at the same time increase end-use efficiency, reduce emissions and provide additional flexibility for the power system and thereby facilitate integration of variable renewables. However, sector coupling faces formidable barriers as taxes and other levies on electricity – and therefore end prices – are much higher than for fossil fuels, in particular heating oil. Even taking into account the much higher efficiency of heat pumps, this difference in charges and pricing is a strong barrier against the deployment of this technology, which today accounts for only 2% of energy consumption for heating. The German government should consider options for removing barriers to sector coupling and creating a level playing field across sectors, otherwise sector coupling will be very difficult to materialise.

To date, not enough attention has been devoted to the electricity distribution sector, which faces important barriers both in terms of physical infrastructure development and regulatory frameworks. Based on a cost-benefit assessment in line with EU Directive 2009/72/EG, Germany has chosen a modular approach requiring mandatory roll-out of smart meters by 2020 only for customers consuming more than 6 000 kWh per year. In addition, the current regulatory framework and remuneration model of network charges do not incentivise DSOs to be more proactive. Going forward, Germany needs to both accelerate the deployment of physical infrastructure and the reform of regulations in order to foster competition and new business models that can unlock the vast potential of demand-side response, and follow the example of other countries, which have implemented a faster roll-out of smart meters on a voluntary basis.

Important progress has been made in the recent EEG reforms, including achieving significant cost reductions thanks to competitive auctions. However, going forward much more additional capacity from wind and solar will be required. The phase-out of nuclear electricity generation is to be completed by 2022. The government coalition has announced a target of 65% of renewables by 2030. The government-appointed commission on coal has proposed a progressive phase-out of coal by 2038, with significant intermediate decommissioning milestones in 2022 and 2030. In this context, the issue of more system-friendly auctions has been discussed thoroughly and several concepts were tested, with the government concluding that grid extensions are the most economic measure. The government has decided that renewable resources should primarily determine the location of renewable installations, but at the same time introduced administrative auction caps in congested zones. Going forward, the government may also want to consider possible alternative and more market-oriented solutions.

The extension and reinforcement of grids will play a critical role towards the achievement of the ambitious 65% renewable share in electricity by 2030. Grids are important in three different respects: smoothing the variability of renewables over a larger balancing area, providing flexibility by connecting renewable supply with demand centres, and enabling additional flexibility by connecting storage, demand-side response and dispatchable supply. The planned 7 700 kilometres of grids to be built or reinforced by the mid-2020s will certainly bring benefits in terms of increasing flexibility, reducing curtailment and enabling a more secure and cost-effective deployment of wind and solar. This can already be seen, as the frequency of negative prices at the electricity exchange has remained stable, despite the increase of renewable electricity installations. However, towards the second half of the decade, TSOs and the government will need to reassess the cost-effectiveness of further grid expansion versus other flexibility options, taking into account technological progress in storage and demand-side response technologies by that time.

In the longer term, all forms of flexibility will need to be unlocked, including demand-side response, affordable storage and more flexible operation of residual fossil fuel plants. Today, the German power system has around 80 GW of peak demand and 200 GW of total installed capacity; thus, energy-only market signals are not enough to trigger investment in flexibility. The market is expected to be shorter in the period 2022-25 and, therefore, to foster investment in flexible resources. However, market prices will also depend on changes in other countries in the European integrated market. The government and the regulator should carefully monitor progress on investment in all forms of flexibility and consider other complementary options to unlock their potential if needed.

Given the scale of required deployment – most notably of wind – the German government should not underestimate other barriers, as shown by recent undersubscribed onshore wind auctions. Those were due to a combination of an empty investment pipeline after the installation rush in 2016-17, along with mounting social acceptance and long permitting procedure issues. These barriers are expected to increase in view of further significant deployment of renewables. They will need to be addressed with inclusive and transparent stakeholder consultation processes, also with the aim of allocating some benefits of the energy transition to local communities. Measures to overcome the situation are currently being discussed within the “AG Akzeptanz” of the German parliament. The measures discussed comprise social acceptance measures and stronger community involvement.

Recommendations

The government of Germany should:

- ☐ Develop a strong strategy supporting the use of renewables in transport, buildings and industry in line with the 2030 targets. Propose measures that support innovation and competition across renewable fuels, including biogas, biomethane, advanced biofuels, and renewable hydrogen-based fuels and feedstocks.
- ☐ Remove the barriers that hinder efficient sector coupling by fostering a level playing field across end-use sectors, including by removing fossil fuel subsidies, introducing carbon pricing in non-ETS sectors, and rebalancing taxes, levies and incentives, while fairly allocating costs and benefits across customer groups.

- Further enhance the overall system efficiency of the EEG by: maximising the system value of renewables with market-based measures, aligning with other measures fostering system flexibility, and addressing social acceptance and permitting issues with stronger community involvement.
- Put a stronger focus on policies for distributed renewables, including regulatory frameworks aimed at a fair cost allocation of infrastructure (e.g. distribution grids, smart meters) that can enable both distributed renewable generation and flexibility resources such as demand-side response and storage.

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6. Energy technology research, development and demonstration

Key data

(2017)

Government energy RD&D spending: EUR 1 013 million

Share of GDP: 0.31 per 1 000 GDP units (IEA* median: 0.30)

RD&D per capita: USD 12.2 (IEA* median: USD 15.2)

Exchange rate: EUR 1 = USD 1.13; USD 1 = EUR 0.89.

* Median of 19 IEA member countries for which 2017 data are available.

Overview

Germany has continued to increase public funding in energy-related research, development and demonstration (RD&D) to meet the targets set out in the 2010 Energy Concept. As renewable energy sources are expected to account for the biggest share in the future energy mix in Germany, a sizeable share of public RD&D funds are invested in clean energy research, including energy efficiency. In addition, funds for nuclear safety research have been important for the past few years to implement Germany's nuclear phase-out programme in a safe and reliable manner. Germany should continue to use energy RD&D to support the energy transition. This includes allocating adequate funding to key priority areas and to monitor the effectiveness of its RD&D policy.

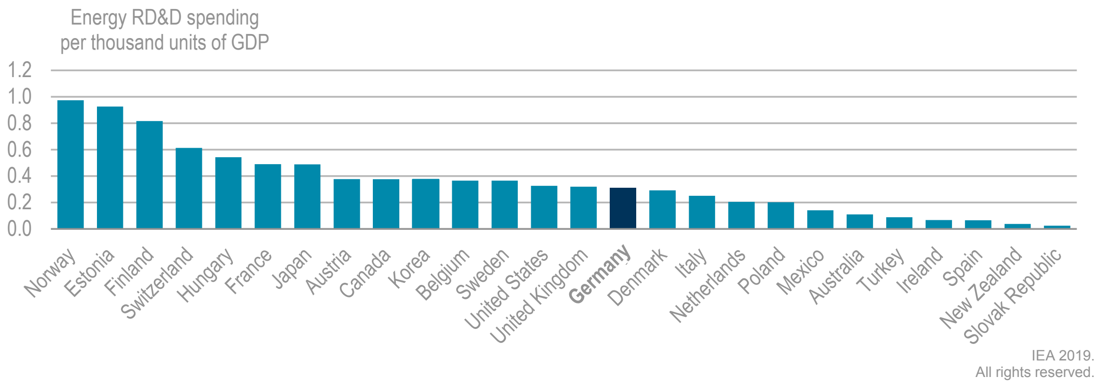
Public spending on energy RD&D

Germany spent 0.031% of its gross domestic product (GDP) in 2017 on energy-related RD&D. As a result, Germany ranked around the median in terms of RD&D expenditure in 2017 among International Energy Agency (IEA) member countries (Figure 6.1). In absolute numbers, Germany's energy RD&D budget was USD 1.01 billion in 2017, the fourth-largest among all IEA member countries.

Germany has steadily increased its public energy RD&D spending in the last decade. In 2017, the federal government spent over EUR 1 billion on energy RD&D, which was 14% higher than the year before and nearly double that of 2008 levels (Figure 6.2). Furthermore, energy research is also funded by the states (*Länder*). In 2016, states' spending totalled more than EUR 248 million.

Allocation of energy RD&D funds reflects the energy transition in Germany. The largest share of public funds went to renewable energy, with 29% of the total, mostly directed at solar and wind research and smaller shares allocated for biofuel and geothermal research. Energy efficiency received the second-largest share, with 22% of the total budget, mainly for research in improving efficiency in the industry sector. Nuclear (including fusion research) accounted for 21%, the third-largest share in terms of total budget. Other power and storage technology received 13% of total public funding while cross-cutting technologies received 8% of the total. Fossil fuels RD&D received only 5% of total public funding, of which more than half went to research on carbon capture and utilisation.

Figure 6.1 Government energy RD&D spending per GDP in IEA countries, 2017

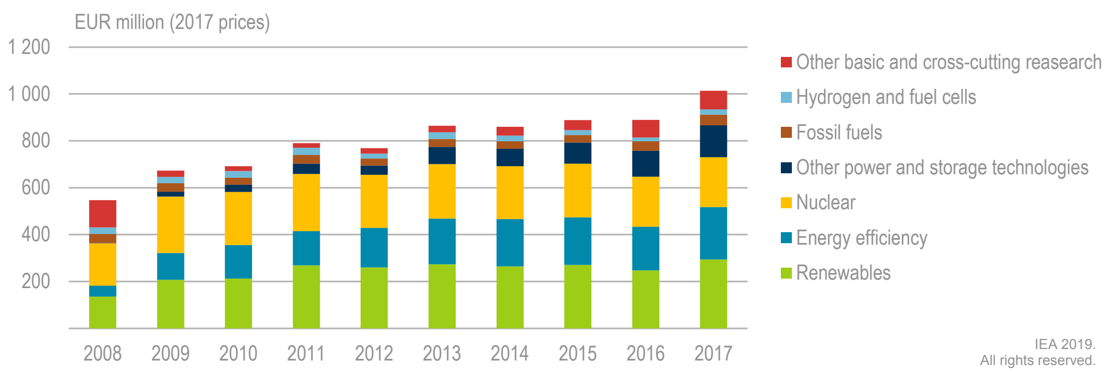


With 0.03% of GDP spent on energy RD&D, Germany ranks around the median in the IEA.

Note: Data are not available for Belgium, the Czech Republic, Finland, France, Greece, Hungary, Ireland, Korea, Luxembourg, Portugal and Spain.

IEA (2019), Energy *Technology RD&D Budgets 2019*: *Overview*, www.iea.org/statistics.

Figure 6.2 Government energy RD&D spending by category, 2010-17



Renewables and energy efficiency received half of public energy RD&D funds, and nuclear funding (safety and fusion research) remains large despite the phase-out of nuclear power.

Source: IEA (2019), Energy *Technology RD&D Budgets 2019*: *Overview*, www.iea.org/statistics.

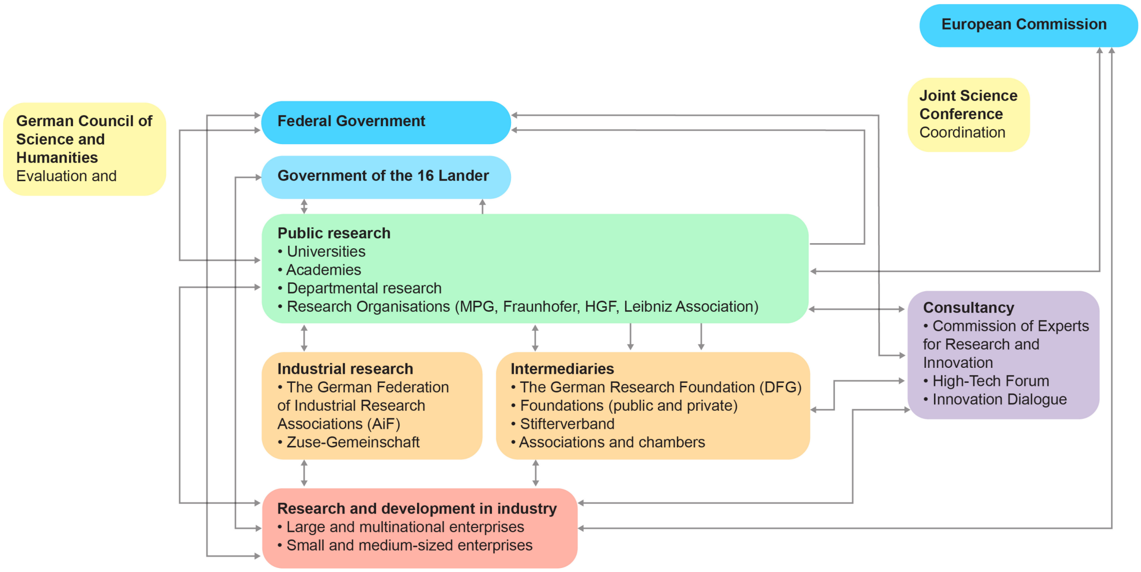
7th Energy Research Programme

The German government recognises the role of technology in achieving the ambitious targets of the energy transition as well as the role of innovation in maintaining the competitiveness of German industry. As such, energy RD&D is an important component of the Energiewende. The government's latest RD&D strategy is embodied in the 7th Energy Research Programme, titled Innovation for the Energy Transition. The programme was adopted in September 2018 and lays out the major guidelines and priorities for federal RD&D funding. The programme was compiled based on a wide-ranging stakeholder consultation process that began in December 2016.

Institutions

Three federal ministries collaborate to enact the agenda under the 7th Energy Research Programme: the Federal Ministry for Economic Affairs and Energy (BMWi), which oversees applied research initiatives; the Federal Ministry of Food And Agriculture (BMEL), which is in charge of bioenergy-related research; and the Federal Ministry of Education and Research (BMBF), which covers all areas of basic research. However, the programme establishes an inter-ministerial, thematic approach to funding initiatives to promote coherence of energy policy goals across the government. All activities under the programme are synchronised by the Co-ordination Platform for Energy Research Policy, comprising representatives from the aforementioned ministries. The federal government also maintains regular communication with the *Länder* on energy research policy.

Figure 6.3 German research and innovation system stakeholders



Source: BMBF (2019), *Federal Report on Research and Innovation*, [www.bundesbericht-forschung-innovation.de/en/Structure-and-stakeholders-1650.html.](www.bundesbericht-forschung-innovation.de/en/Structure-and-stakeholders-1650.html)

Funding levels

Under the 7th Energy Research Programme, for 2018-22, the federal government plans to provide a total of EUR 6.4 billion for energy RD&D (around EUR 1.3 billion per annum), testing viable future technologies and concepts. This amounts to a notable increase of about 45% compared with the previous period of 2013-17. Financing of the programme comes from the federal budget and the Energy and Climate Fund, which receives revenues from the auctioning of emissions permits (though are only available for direct project funding of non-nuclear projects).

Table 6.1 Germany's 7th Energy Research Programme

In EUR thousands	Target	Government draft	Plan data		
	2018	**2019**	**2020**	**2021**	**2022**
BMWi	**639 700**	**725 205**	**725 798**	**723 800**	**723 745**
Project funding	595 596	682 980	682 980	682 980	682 980
Institutional funding (DLR)	44 104	42 225	42 798	40 820	40 765
BMEL					
Project funding	46 803	46 803	46 803	46,803	46 803
BMBF	**506 613**	**515 601**	**528 018**	**521,809**	**521,809**
Project funding	133 427	133 261	133 355	133 355	133 355
Institutional funding (DLR)	373 186	382 340	394 663	388 454	388 454
Total	**1 193 116**	**1 287 609**	**1 300 599**	**1 292 412**	**1 292 357**

Note: DLR = German Aerospace Center.
Source: BMWi (2018a), *Innovations for the Energy Transition:7th Energy Research Programme of the Federal Government*, www.bmwi.de/Redaktion/EN/Publikationen/Energie/7th-energy-research-programme-of-the-federal-government.pdf?blob=publicationFile&v=5.

Through the 7th Energy Research Programme, the government will increase direct funding on projects rather than on institutions. The programme follows a dual strategy with respect to funding instruments. One-third of the available budget is directed towards institutional funding of the Helmholtz Association of German Research Centres (HGF), Germany's largest scientific organisation, focusing on long-term research objectives. The share for direct competitively funded projects with shorter-term objectives was recently increased to two-thirds of the total budget. The programme classifies projects based on their technology readiness level, falling under three basic categories: basic applied research, research nearing application and living labs.

Priority areas

Funding priorities under the 7th programme will be based on systemic and inter-systemic issues of the energy transition, rather than on individual technologies. Among the focus areas are:

- Energy transition in end-use sectors, focused on energy efficiency, cutting consumption and increasing the role of renewables in final consumption.
- Transport sector technologies, such as batteries, fuel cells and biofuels.
- Power generation technologies, including the full range of renewable and thermal generation plants.

- System integration of renewables, including grid development, energy storage and sector coupling.
- Intersystem research areas, such as digitalisation, resource management and carbon technologies.
- Nuclear safety research, focused on the safe operation of nuclear power plants through 2022 as well as management of the decommissioning of nuclear plants and radioactive waste disposal.

As part of the 7th programme, the government also places a strong focus on social acceptance of new technologies, especially in areas such as digitalisation. Therefore, the concept of stakeholder engagement is integrated with energy RD&D efforts.

Living labs

Importantly, with the 7th research programme, the government has shifted its strategic direction to technology and innovation transfer. In this regard, the programme emphasises the funding of living labs that can help bring innovative technologies to market and up to commercial scale.

Living labs allow for the testing of new technologies that are close to market-ready in controlled real-world settings. They are cross-cutting demonstration projects on an industrial scale.

Living labs for the energy transition have been introduced as a new funding format in the 7th Energy Research Programme, but they will draw on experience gained from previous funding initiatives. One of these is the Smart Energy Showcases – Digital Agenda for the Energy Transition (SINTEG) programme. Under SINTEG, five model regions have been set up to test digital applications to address technical, economic and regulatory challenges (BWMi, 2018b). A first call for living labs for the energy transition focused on hydrogen technologies for use in heating, transport and industry and on energy-efficient city quarters, and will be supported by EUR 100 million per year.

The participation of technology start-ups also receives greater attention under the programme. Specifically, start-ups will have improved access to research funding and will be able to partner with research institutes and companies to develop innovative solutions (BMWi, 2018c).

Kopernikus projects

The Kopernikus projects are one of the largest Energiewende research initiatives of the federal government, focused on various aspects of system integration of renewables. The projects run over a ten-year horizon and are undertaken in close collaboration with industry. They encompass four core research areas:

- development of electricity networks (Kopernikus project ENSURE)
- storage of surplus renewable energy by conversion into other energy carriers (Kopernikus project P2X)
- adaptation of industrial processes to fluctuating energy supply (Kopernikus project SynErgie)
- improved interaction among all sectors of the energy system (Kopernikus project ENavi).

The projects and topics were developed based on collective input from high-level representatives from over 90 institutions from the scientific, business and civil society communities as part of the Energiewende Research Forum.

The BMBF allocated up to EUR 120 million for an initial three-year funding of the projects starting in 2016, followed by another EUR 280 million to 2025.

Information sharing

The government recognises that beyond funding, communication and dissemination of research findings and trends is an important aspect of RD&D policy. Moreover, communication also ensures transparency in the funding allocation process.

To this end, a central information system for energy research funding, EnArgus, is run as a web-based database with over 24 000 energy research projects. The database forms the basis of the government's annual progress report to parliament and the public, the *Federal Government Report on Energy Research*. The government plans to expand the database over the coming years.

Furthermore, in an effort to ensure broad social consensus on the energy agenda and on energy research, the government established a website (energieforschung.de) for sharing information on research issues and progress on research projects. In addition, the government oversees a multimedia website to share information on energy research activities along three flagship initiatives: Transformation of the Energy System, Green Economy and the City of the Future.

The Energy Transition Research and Innovation Platform was established by the BMWi to facilitate the dialogue and co-ordination among ministries at the federal and state levels as well as high-level stakeholders from policy making, science, business, industry and civil society. In this regard, the platform serves as an energy advisory body to the BMWi on energy research efforts. Topical expert groups, drawn from the energy research networks, provide the input to discuss and assess the priority setting of RD&D policy. The first meeting of the platform was held in May 2015 and the most recent meeting took place in February 2019 (BMWi, 2019). The platform is supported by eight thematic energy research networks, including one for start-ups.

The German government regularly conducts scientific and technical evaluations as well as ongoing performance reviews to examine the efficiency and effectiveness of its RD&D funding. Not only does the evaluation process increase transparency among the ministries involved in RD&D efforts, it also helps to ensure that future funding is awarded in a more effective manner. Moreover, in advance of funding selections, applicants must include work plans and milestones that also support ongoing evaluations of projects.

International collaborations

The 7th Energy Research Programme also places greater emphasis on the co-ordination of research efforts internationally as well as with other European countries.

At European level, Germany is contributing to strategic projects on non-nuclear energy topics under the framework of the Strategic Energy Technology (SET) Plan and the European Union Framework Programme for Research. Germany is also very active in research collaborations organised by the IEA. It participates in 22 Technology Collaboration Programmes (TCPs), out of 38 available programmes. This is the fifth-highest number after the United States, Japan, Korea and Canada. Germany participates in most TCPs related to energy consumption (buildings, transport and industry), renewable energy and hydrogen.

Germany, through the BMWi, has also been active in various fora established under the Clean Energy Ministerial (CEM) since 2009, and contributes mainly on topics related to smart grids and electric vehicles. Specifically, Germany is a co-leading sponsor of the Multilateral Solar and Wind Working Group, CEM Investment and Finance, Power System Flexibility, and Long-Term Energy Scenarios for the Clean Energy Transition. Beyond those, it also participates in seven additional CEM initiatives.

Germany is also a member of the Mission Innovation (MI) initiative, serving as a co-lead on two work streams: Converting Sunlight Innovation Challenge and Renewable and Clean Hydrogen Innovation Challenge. It also participates in an additional four research areas: Smart Grids Innovation Challenge, Carbon Capture Innovation Challenge, Clean Energy Materials Innovation Challenge, and Affordable Heating and Cooling of Buildings Challenge.

Germany also participates in numerous bilateral research activities through the Agreements on Scientific and Technological Co-operation (S&T). In 2018, Germany had 47 S&T agreements with governments around the world. Under the 7th Energy Research Programme, Germany is planning to especially focus on bilateral partnerships with France, Greece and Australia as well as to develop partnerships with African countries.

Germany's energy RD&D policy aims to strengthen industrial locations in Germany and Europe, alongside expediting the energy transition. Hence, for Germany, the export potential for climate-friendly technologies is of major importance in setting funding priorities and choosing topics for international collaboration.

Assessment

The goals of the Energy Concept 2010 cannot be reached by only relying on mature technologies. In order to accelerate the rate of technology development and innovation transfer, the federal government recently approved the 7th Energy Research Programme Innovation for the Energy Transition. Compared with the 2013-17 period, the available funding has increased by 45%.

The energy RD&D policy follows a dual strategy with respect to funding instruments. One-third of the available budget is directed towards institutional funding of the HGF, focusing on long-term research objectives. The share for competitively funded projects with shorter-term objectives was recently increased to two-thirds.

While the federal government spent over EUR 1 billion on energy RD&D in 2017, the federal states contributed an additional EUR 248 million. The latter consisted of both basic financing of research centres and competitive project funding. Due to the priorities and financial situations of the federal states, their contributions to energy RD&D will not increase at the same rate compared with federal policy.

The Energy Transition Research and Innovation Platform was established to facilitate the dialogue and co-ordination among ministries at the federal and state levels as well as high-level stakeholders from policy making, science, business, industry and civil society. Topical expert groups provide the basic input to discuss and assess the priority setting of RD&D policy. A process to allocate research funds ex ante to different innovation stages and key priority areas has been developed and will be implemented in 2019.

In order to support the development of new technologies towards commercialisation in an integrated approach, a new instrument to establish large-scale "living labs" has been introduced. In addition, access to federal RD&D funding for start-up companies is being improved. Policy measures currently do not include instruments to support the full path to market, such as, for example, access to venture capital. These projects can explore the interaction of technological and regulatory features and identify systemic optimisation potentials.

The federal government has been providing energy RD&D funding to a wide variety of technological areas. Nevertheless, many issues related to energy and climate policy goals can only be solved in an interdisciplinary manner. The IEA acknowledges the recent introduction of a new focus area on systemic and inter-systemic issues and, thus, the strengthening of non-technological research (such as into behavioural and social aspects) in energy RD&D policy. This instrument is of particular interest to address social acceptance issues and upcoming long-term challenges in view of the coal phase-out and the decarbonisation of the heat and transport sectors.

The funding for nuclear RD&D (including basic research for nuclear fusion technologies) remained at a constant level in the past few years, despite the decision to phase out nuclear reactors in Germany. In order to decommission the power plants, to handle the radioactive waste and to participate in international collaborations, a high level of scientific expertise is of utmost importance. The continuous engagement in nuclear safety research is a key element to secure knowledge and to educate young scientists and technicians.

In order to support the knowledge and technology transfer as well as to establish a quantitative basis to assess public RD&D funding, a sophisticated energy information system was successfully introduced. The IEA acknowledges the quality of the database and supports ongoing efforts by the federal government to work towards a complete dataset and, thus, to also include RD&D funded by the federal states.

The energy RD&D policy of the federal government aims to strengthen industrial potential in Germany and Europe. The export potential globally for innovative technologies is of major importance in choosing areas for international collaborations. As an example, Germany took a leading role in the area of hydrogen and solar conversion technology in the MI campaign. Due to the new energy RD&D policy, Germany is on track to meet the commitment to double federal RD&D expenditures over a five-year period.

Recommendations

The government of Germany should:

- Maintain adequate funding for research infrastructure as well as fundamental and applied research, including nuclear research, to address mid- and long-term objectives of energy policy.
- Implement a coherent and transparent process to allocate funding to identified key priority areas and to different stages in the innovation chain.
- Monitor the effectiveness and efficiency of new funding instruments, and derive best practices to be shared on a national and international level.
- Encourage the path to market for "living labs" by facilitating greater links between RD&D programme participants and private financiers.

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7. Electricity

Key data

(2018 provisional)

Electricity generation: 644 TWh (coal 37.5%, nuclear 11.8%, natural gas 13.2%, wind 17.3%, bioenergy and waste 9.1%, solar 7.4%, hydro 2.8%. oil 0.8%, geothermal 0.03%), +1% since 2008

Electricity net exports: 48.7 TWh (imports 31.7 TWh, exports -80.5 TWh)

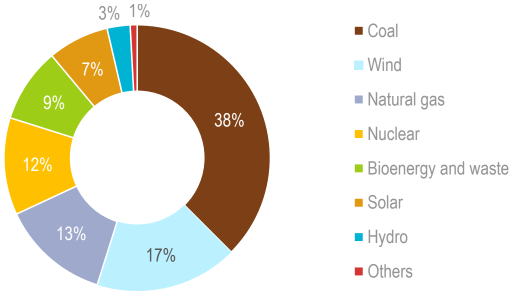
Installed capacity (2017): 215.5 GW

Electricity consumption (2017): 531 TWh (industry 42.9%, commercial 28.4%, residential 24.1%, transport 2.3%, other energy 2.3%)

Overview

Germany's Energiewende has borne results in the country's electricity sector, where it has been effective in increasing renewable electricity generation. While coal (mainly lignite) remains the largest source of electricity, renewables have replaced a large share of nuclear over the last decade. In 2017, wind power surpassed both nuclear and natural gas to become the second-largest source of electricity generation (Figure 7.1). Continued growth in renewables in line with Germany's energy and climate targets will require a number of measures for advancing electrification and system integration of renewables, including improvements to taxation, market regulation, and the transmission and distribution infrastructure.

Figure 7.1 Electricity generation by source, 2018



Renewables are growing rapidly in Germany, particularly wind power, which has become the second-largest electricity source, but fossil fuels still account for over half of total generation.

Note: Data are provisional.

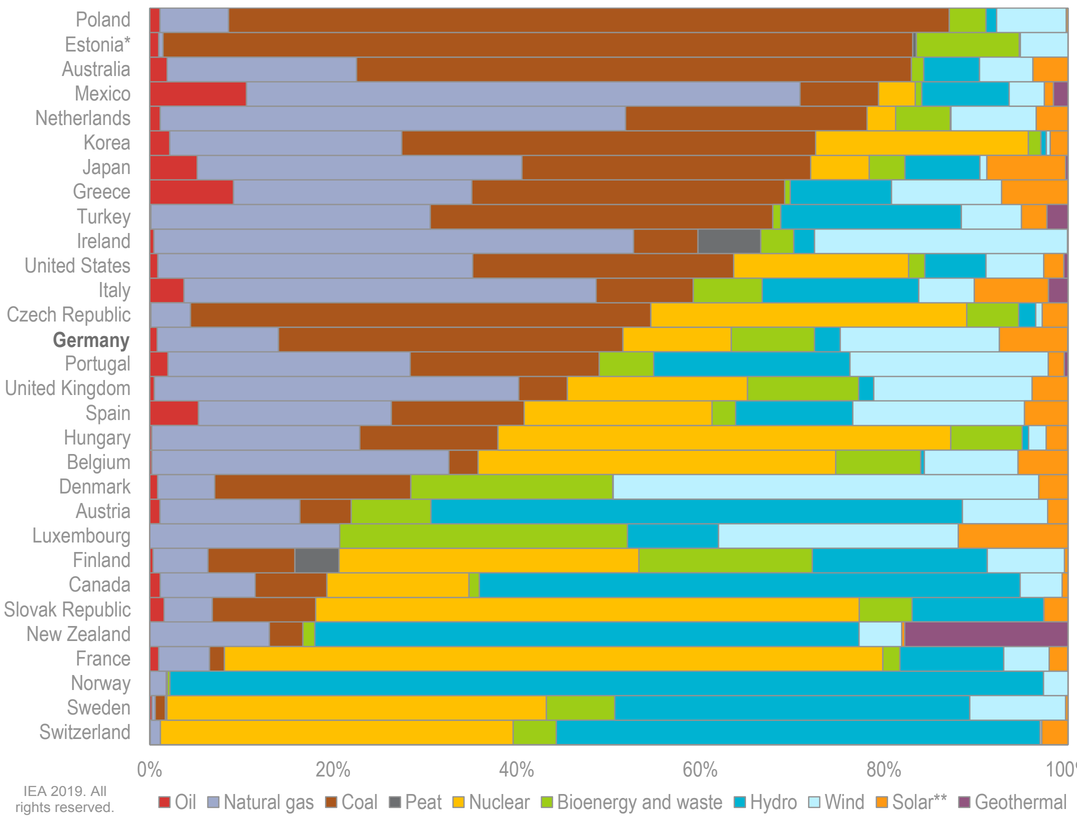
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Electricity supply

Electricity generation and trade

Electricity generation in Germany still relies heavily on fossil fuels. Coal, natural gas and oil together accounted for 52% of the total power generated in 2018 (though oil accounted for a very small share). This places Germany in the middle among International Energy Agency (IEA) countries in terms of the share of fossil fuels in electricity generation (Figure 7.2).

Figure 7.2 Electricity generation by source in IEA, 2018



With 52% of fossil fuels used for electricity generation, Germany is using more fossil fuels than the average 47% in IEA member countries.

*Estonia's coal represents oil shale.

***Solar* includes solar PV, solar thermal, wave and ocean power, and other power generation (e.g. from industry waste heat and fuel cells).

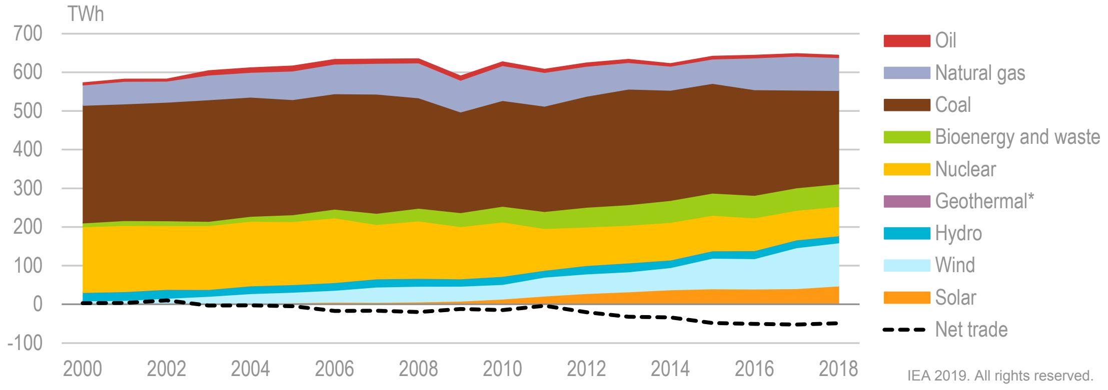
Note: Data are provisional.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Coal is the major source of electricity produced in Germany, with 38% of total generation in 2018. However, its share is declining, down from close to 50% a decade earlier (Figure 7.3). Furthermore, nuclear power has been reduced by almost half in a decade, mainly replaced by the increased use of renewable energy sources, strongly supported by feed-in tariffs (FiTs). The share of renewable energy grew from 15% in 2008 to 35% in 2018. In particular, wind power has been growing exponentially, and more than doubled its production in the last five years. In addition, solar power and bioenergy have increased significantly in the last decade.

The energy transition will continue to impact Germany's electricity generation for decades. As the government plans to shut down all nuclear facilities by the end of 2022 and all coal plants by 2038, the power sector's trajectory will continue to be dominated by growth in renewable energy.

Figure 7.3 Electricity supply by source, 2000-18



Total power generation has been stable at around 630 TWh over the last decade, but there has been a significant fuel shift from nuclear power to renewables.

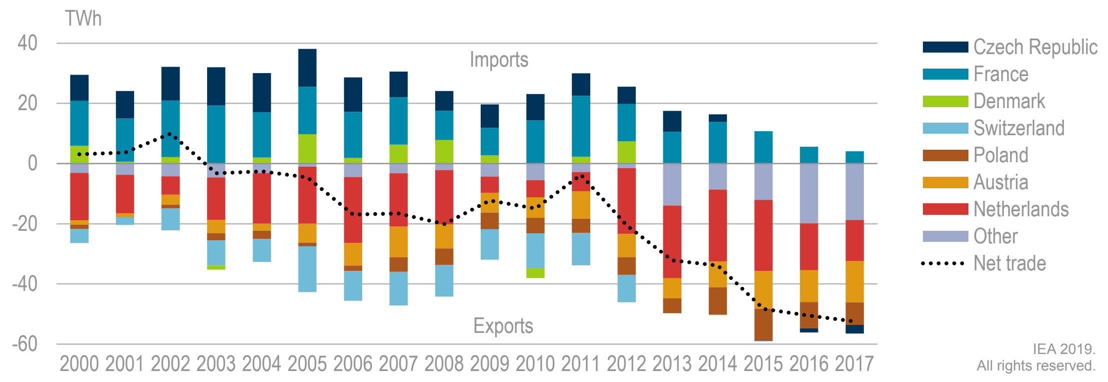
*Not visible on this scale.

Notes: TWh = terawatt-hours. Supply data for 2018 are provisional.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Germany is at the heart of the European power market and interconnected with many neighbouring countries, which enables international power trade. With its rapid growth in renewables, Germany has become a large net exporter of electricity. In 2018, Germany exported 80 TWh and imported 32 TWh, amounting to net exports of 49 TWh. The largest share of Germany's net exports went to the Netherlands, Austria and Poland, while imports came mostly from France (Figure 7.4).

Figure 7.4 Electricity net imports and exports by country, 2000-17



Germany is interconnected with many neighbouring countries, and the growth in renewable power generation has led to increased electricity exports.

Source: IEA (2019b), *Electricity Information 2019*, www.iea.org/statistics/.

The energy transition towards renewables is even more visible when looking at installed capacity (Table 7.1). Total installed capacity increased by 32% between 2010 and 2017, largely from significant increases in wind and solar power. Installed wind power capacity more than doubled from 27 gigawatts (GW) in 2010 to 56 GW in 2017, and solar power capacity increased from 18.0 GW to 42.3 GW. Installed capacity in power plants using combustible fuels increased by 25% during the same period, from 76.4 GW in 2005 to 95.1 GW in 2017, largely from new bioenergy plants. Meanwhile, nuclear power generation capacity has been almost halved compared with 2010 and hydro capacity remained stable at around 11 GW over the same period.

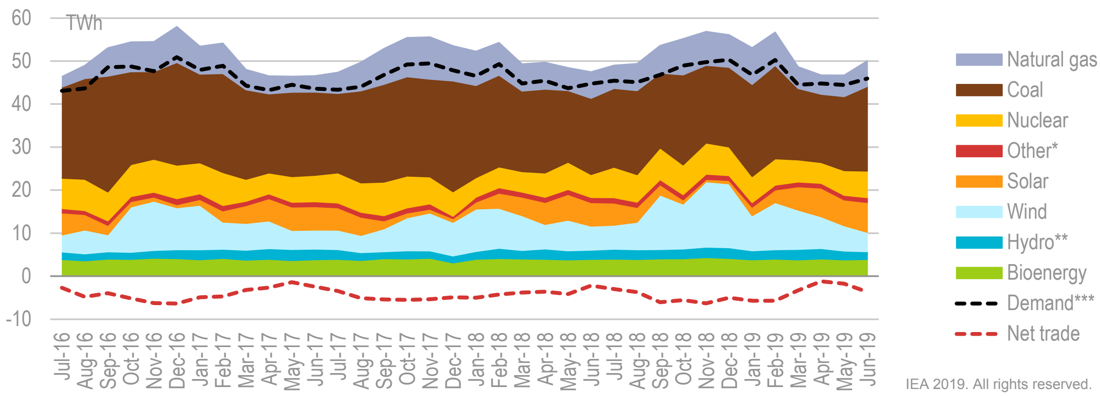
Table 7.1 Installed electricity generation capacity, 2005-17 (GW)

	2005	2010	2011	2012	2013	2014	2015	2016	2017
Nuclear	20.4	20.5	20.5	12.1	12.1	12.1	10.8	10.8	10.8
Hydro	10.9	11.2	11.4	11.3	11.2	11.2	11.4	11.3	11.1
Wind	18.2	26.9	28.7	31.0	33.5	38.6	44.6	49.6	55.7
Solar	2.1	18.0	25.9	34.1	36.7	37.9	39.2	40.7	42.3
Other sources	0.6	0.4	0.5	0.4	0.4	0.5	0.4	0.3	0.4
Combustible fuels	76.4	85.8	89.4	89.6	91.4	97.2	97.0	95.7	95.1
Total capacity	128.5	162.9	176.4	178.4	185.3	197.5	203.4	208.5	215.5

Source: IEA (2019b), *Electricity Information 2019*, www.iea.org/statistics/.

Power generation peaks during the winter, when heating demand is the highest. This is also the case for neighbouring countries, and Germany increases its exports during the winter months (Figure 7.5). The increased share of variable renewable power generation from solar and wind is balanced by dispatchable generation from natural gas and coal plants. However, while solar power is in high supply in the summer, wind power generation peaks in winter, which matches demand well.

Figure 7.5 Monthly electricity generation by source, July 2016-June 2019



Germany's electricity generation peaks in the winter to cover domestic demand as well as increased exports.

**Other* includes oil, geothermal and other non-specified generation.

***Hydro* excludes production from pumped storage plants.

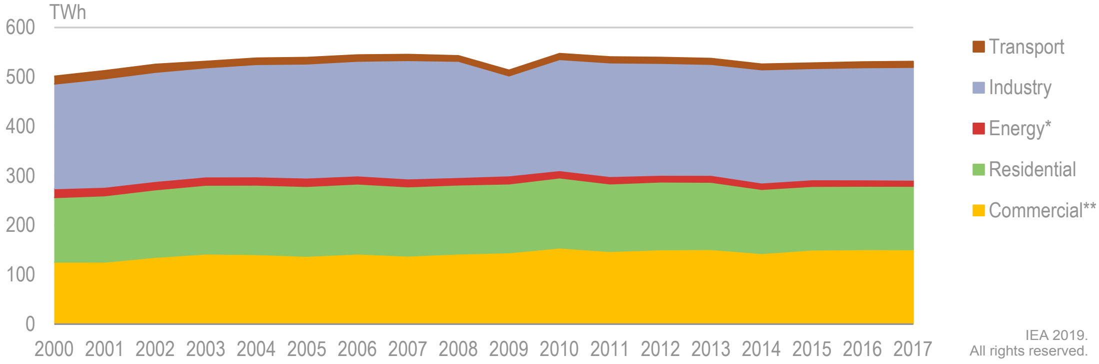
****Demand* refers to final consumption including distribution losses.

Source: IEA (2019c), *Monthly Electricity Information 2019*, www.iea.org/statistics/.

Electricity consumption

Total electricity consumption has been relatively stable at an average of around 530 TWh over the last decade. The only exception was a decline in 2009, in the aftermath of the financial crisis, which led to reduced energy demand in industry. The residential and commercial sectors together accounted for 52% of Germany's total final consumption (TFC) in 2017, followed by 43% for the industry sector and small shares for transport and energy (Figure 7.6). In a ten-year comparison from 2007 to 2017, electricity consumption fell across all sectors except the commercial sector, which increased by nearly 10%. Residential consumption dropped by 8%, while industry consumption fell by 5% after recovering from a sharp decline in 2009 amid the financial crisis.

Figure 7.6 Electricity consumption (TFC) by consuming sector, 2000-17



Electricity consumption is relatively stable in Germany, with a small shift from the industry and residential sectors to the commercial sector.

**Energy* includes petroleum refineries, coal mines, oil and gas extraction, coke ovens, and blast furnaces.

***Commercial* includes commercial and public services, agriculture, and forestry.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

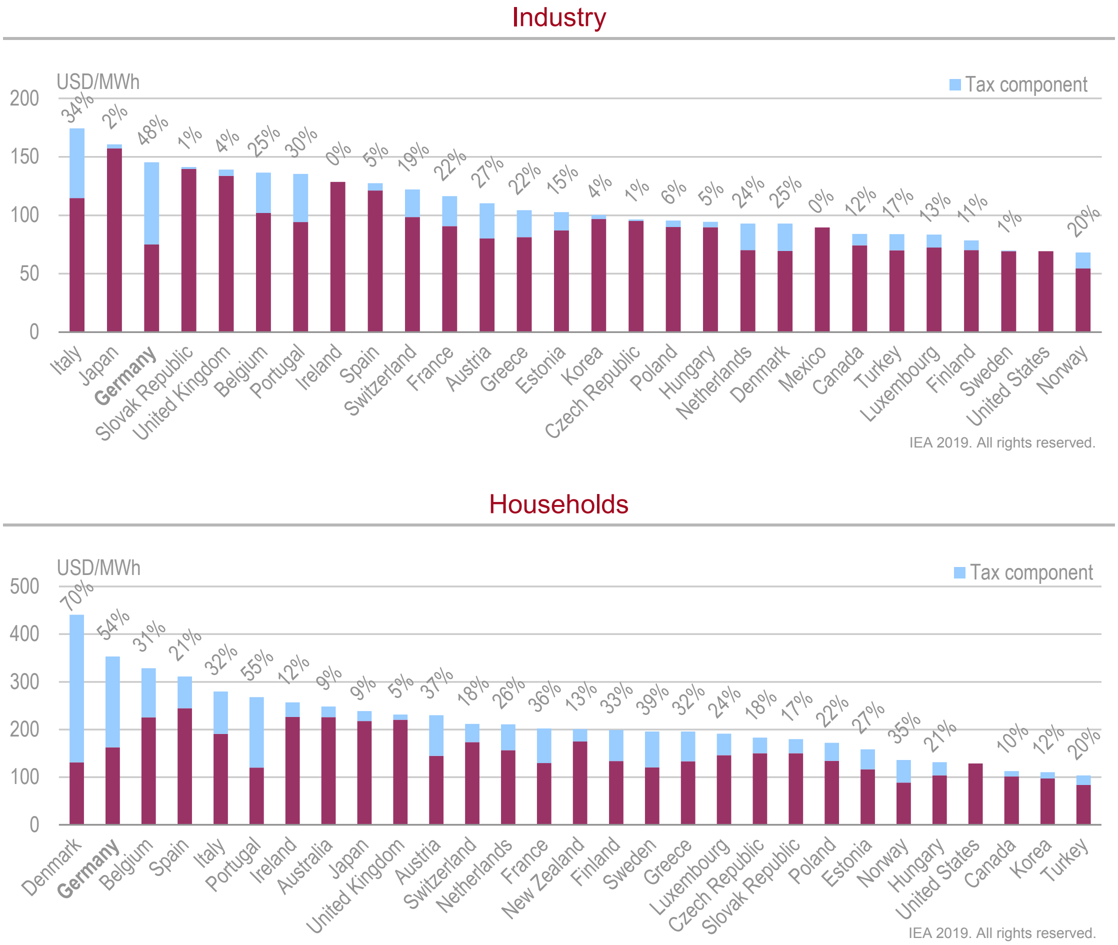
Electricity market structure and regulation

Prices and taxation

Germany's consumers pay among the highest electricity prices in the IEA, mostly because of levies, charges and taxes, including levies to pay for renewables subsidies. The country ranked third among IEA member countries in terms of industry electricity prices in 2018 (Figure 7.7), though energy-intensive industries receive significant price relief. Taxes account for 48% of total industry prices, which is the highest among IEA members. The total electricity price that households paid, of which about half consist of public charges, ranked second after Denmark. End-use prices in Germany are not regulated.

Compared with several neighbouring IEA countries, the price of electricity in Germany has risen the most in the past decade (Figure 7.8). Despite a price drop in 2015, Germany's electricity prices for both the industry and household sectors rose about 10% in the past decade. In 2018, industry consumers paid an average of USD 145 per megawatt-hour (MWh), a 13% increase from 2008, while households paid USD 353/MWh, a 9% increase from 2008.

Figure 7.7 Electricity prices in IEA member countries, 2018

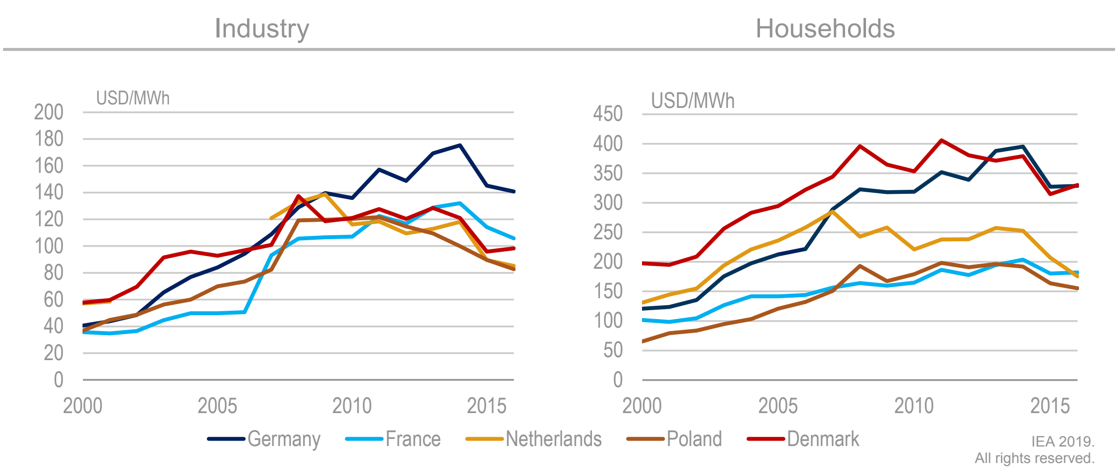


*Data for 2018 are provisional. No tax information available for the United States.

Note: The tax component includes value-added taxes and excise taxes, levies and public charges.

Source: IEA (2019d), *Energy Prices and Taxes 2019*, www.iea.org/statistics/.

Figure 7.8 Electricity prices in Germany and selected IEA countries, 2000-18



Source: IEA (2019d), *Energy Prices and Taxes 2019*, www.iea.org/statistics/.

Institutions

The Bundesnetzagentur is the lead federal regulatory authority for the electricity sector. Though it is situated under the authority of the Federal Ministry for Economic Affairs and Energy (BMWi), it operates independently. The Bundesnetzagentur is responsible for "larger" system operators, including transmission system operators (TSOs) and distribution system operators (DSOs) with large numbers of connection points and operators acting in more than one state. Usually, regional authorities regulate smaller DSOs (with fewer than 100 000 customers).

In addition, the Bundeskartellamt regulates competition in the electricity sector, including monitoring merger activity and potential anti-competitive behaviour on the part of market participants. The Federal Financial Supervisory Authority (BaFin) regulates electricity trading.

Electricity market structure

Although there are several hundred power providers, over half of the country's conventional electricity is generated by four large utilities: E.ON, RWE, Vattenfall and EnBW. An additional 25% comes from public utilities that operate at the regional or city level. For renewable power, there is a much larger, more eclectic group of producers, including project developers, power companies, municipal utilities and households/farmers. Offshore wind and utility-scale solar projects are usually developed by professional project developers.

Germany's transmission system consists of four TSOs: Amprion, TenneT, 50Hertz and TransnetBW. The German transmission system serves as an important hub in the European electricity market as well.

In addition, there are over 800 DSOs in Germany, and most of them have less than 100 000 customers; the smaller DSOs have around 30 000 customers on average.

On the retail level, the market share for the four largest companies is sizeable but below 40%. End users in Germany in 2017 could choose among 143 suppliers in their network areas, while households could choose among 124 suppliers. In 2017, 41.2% of households had contracts with their default supplier, compared with 27% for metered non-households. The rate of switching among non-households in 2017 was 13%, compared with 7.2% for households.

Electricity market operation

The German electricity market is composed of various trading markets (e.g. wholesale and balancing, futures, day-ahead and intraday) in which price signals inform electricity generation and consumption. Generation sources with the lowest variable costs are the first in the merit order to meet demand. The final wholesale price is determined on a single price zone and based on the most expensive generation source in the market, or the marginal power plant. Marginal costs are primarily influenced by fuel costs, power plant efficiency and carbon prices. As such, renewable power tends to place first in the merit order, given near-zero marginal costs.

TSOs use balancing capacity to address unanticipated discrepancies between supply and demand, such as plant outages or unexpected consumption changes. TSOs classify balancing capacity as either positive, which takes the form of increased production or reduced consumption, or negative, which takes the form of reduced production or increased consumption.

In addition, TSOs distinguish three types of balancing capacity:

- primary balancing capacity, which needs to be fully available within 30 seconds of being called upon
- secondary balancing capacity, which needs to be available within five minutes
- tertiary balancing capacity, also known as the minute reserve, which needs to be available within 15 minutes.

A system of balancing groups and imbalance settlement ensures a balanced grid. The electricity system regulator, Bundesnetzagentur, requires that balance responsible parties (BRPs) assign all generators and consumers into balancing groups and develop schedules (on 15-minute increments) based on generation and load forecasts. It also requires BRPs to incur costs for any unexpected imbalances through an imbalance settlement system. TSOs serve as BRPs in this context.

The introduction of large volumes of renewable power into the German grid has increased volatility in wholesale prices (see Chapter 5 on renewables). When an abundance of wind generation coincides with periods of low demand, prices can plummet and even turn negative. Conversely, on non-windy days during periods of peak demand, prices can surge. As a result, demand for baseload and mid-merit plants is falling in favour of peaking plants and demand-side management services.

Grid stabilisation

Most wind capacity is located in northern Germany, whereas most demand comes from metropolitan and industrial areas in the south and west of the country. As a result, northern states are facing power surpluses while southern ones are experiencing deficits, an imbalance that will worsen as the last of the country's nuclear facilities close and more offshore wind comes online. The imbalance has resulted in significantly increased "re-dispatch" measures in the south (where grid operators order power stations to ramp up output to compensate for procured wind power that cannot make it south) and curtailment in the north (where grid operators order wind power to shut down to avoid congestion), costing consumers hundreds of millions of euros annually. Grid operators estimated that these kinds of grid stabilisation measures were required on 329 days in 2017. The imbalance also creates "loop flows" to neighbouring countries, which have had to invest in grid enforcement and special transformers to maintain security of electricity supply.

Regional trade

Germany's electricity market is connected to several neighbouring countries. Germany previously shared a common bidding zone with Austria, which was split into two zones in October 2018 (Laurent, 2018).

In the day-ahead market based on net transfer capacities (NTC), Germany is currently connected to 18 countries (Austria, Belgium, Denmark, Estonia, Finland, France, Italy, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Portugal, Slovenia, Spain, Sweden and the United Kingdom, as well as Poland via cable to Sweden). In the day-ahead market based on flows, it can trade with six countries (Austria, Belgium, France, Luxembourg, and the Netherlands). Moreover, in intraday markets based on NTC, it is connected to 14 countries (Austria, Belgium, Denmark, Estonia, Finland, France, Latvia, Lithuania, Luxembourg, the Netherlands, Norway, Portugal, Spain, and Sweden).

Trading

In Germany, electricity is traded over exchanges, which include the European Energy Exchange (EEX) in Leipzig and the European Power Exchange (EPEX SPOT) in Paris (EPEX SPOT is now a part of the EEX group). Companies, however, usually directly enter into supply contracts with electricity providers. Trading occurs on forward, day-ahead and intraday markets. Forward contracts are for up to six years in the future, whereas day-ahead and intraday trades occur via auction on the spot market.

Electricity market regulation

The German electricity market was fully liberalised in 1998, based on European Union (EU) efforts to liberalise the internal energy market. Specifically, the European Union's First Energy Package for electricity (1996) directed market liberalisation by 1998. In response, Germany passed the National Energy Act of 1998, under which the previous structure of regional, vertically integrated monopolies was dismantled, and the unbundling of production and transmission segments of the industry began (Brandt, 2006). Price controls were also removed, shifting to a market-based system of price setting.

Additional liberalisation came with the European Union's Second Energy Package (2003), which required regulated third-party access and mandatory unbundling of electricity production and transmission. In particular, member states could no longer choose between negotiated and regulated network access; rather, they were required to provide for regulated network access. These changes, which were implemented into law in Germany under the National Energy Act of 2005, brought further changes in the retail sector, in particular, giving both industrial and household consumers greater choice in electricity suppliers.

Electricity market 2.0

The introduction of large amounts of variable renewables into Germany's power system has challenged the financial picture for large utilities, prompting the government to consider changes to electricity policy and regulation. Beyond the changes to renewables subsidy support starting in 2014 (see section below on "Energiewende in the electricity sector"), the government also launched a broad consultation process on the design of electricity markets. In 2014, the BMWi published a Green Paper that served as a discussion document to guide future regulatory changes, followed by a White Paper in 2015 that included recommendations for change.

The Green Paper and White Paper process prompted parliamentary changes to wholesale market regulations. Specifically, the government decided to gradually eliminate distortions in the regulatory framework and strengthen electricity price signals in a more advanced electricity market, dubbed the Electricity Market 2.0. In June 2016, significant changes to the regulatory framework were part of the Act on the Further Development of the Electricity Market. The goal of the policy was to make the electricity market suitable to accommodate growing shares of variable renewable energy and to establish rules for competition between flexible supply, flexible demand and storage. The act laid down provisions such as a guarantee of free price formation in the wholesale market, new remuneration rules for re-dispatch, tougher rules for sufficient power procurement, more competition to provide flexibility services, reduced costs for grid expansion, and extension of the network reserve of power plants. Market players are free to decide which flexibility options to use (e.g. storage, gas peakers, demand-side management), under a market-driven approach that is intended to keep the overall cost of electricity supply down and to encourage innovation.

In addition, the act called for a strictly separate capacity reserve of 2 GW. Technology-neutral tenders determine which plants enter the reserve and at what cost. In addition, the act ordered the creation of a last-resort reserve (known as Sicherheitsbereitschaft in German) of decommissioned lignite power plants that receive compensation to serve as backup for a period of four years. Eight lignite plants with a collective capacity of 2.7 GW were selected to enter the Sicherheitsbereitschaft reserve at a cost of EUR 1.6 billion (Raus, 2016). Importantly, the reserves can contain only power plants that are not part of the power market and would be called upon only should the market fail to deliver sufficient supply. The European Commission authorised the capacity reserve under state aid rules in February 2018, and it entered into force in February 2019.

Electricity 2030

In order to broaden the scope of the Electricity Market 2.0 and help Germany to meets its 2050 climate targets, the BMWi in September 2016 launched a process known as Electricity 2030, with the release of an input paper. The discussion paper included a wide range of topics based on 12 trends in the energy sector, including the future of electricity generation and transmission as well as opportunities for sector coupling in heating, transport and industry (Table 7.2). As such, the government plans to transition from the Electricity Market 2.0 to an Energy Market 2.0. The discussion paper will form the cornerstone of work being conducted by two task forces within BMWi: the Electricity Market Platform and the Energy Grids Platform.

Clean Energy for All Europeans

In the first half of 2019, the European Union finalised sweeping energy sector reform as part of the Clean Energy for All Europeans package, with an eye to 2030 climate and energy targets. The package consists of eight directives and regulations, dealing with various aspects of the energy space. The second part of the legislative reforms is focused on the internal market for electricity. Among the reforms are a requirement for all utilities with more than 200 000 customers to offer flexible rates to help support the growth in smart meters, facilitate the ability of large consumers to resell unused capacity, and grant priority dispatch for renewables (which is already the case in Germany). In addition, member states are now required to consider neighbouring generation capacity when designing energy security mechanisms to reduce the level of reserve capacity needed. The new Risk-Preparedness Regulation also requires that member states create risk-preparedness plans outlining national and cross-border action to prevent and address potential crisis situations (European Parliament, 2019).

Of particular importance for Germany, the new Electricity Market Regulation calls for interconnectors to be opened to more cross-border trade (see section on transmission and distribution below). Specifically, trading capacity across borders is supposed to increase to 70% of generation capacity. In a similar vein, member states are supposed to address domestic gridlock on their grids. In order to ensure 70% accessibility for cross-border trade, the ability for member states to address internal gridlock by blocking interconnectors and prioritising domestic supply will become more limited. Member states can opt to address internal gridlock by dividing up their electricity market into multiple bidding zones or to submit an action plan on how they will alleviate the gridlock. Germany does not wish to split its electricity market into two bidding zones, which would hamper the trust of market participants in stable framework conditions as a basis for their investment decisions, and is working on a plan to increase cross-border capacity to 70% by 2025.

Table 7.2 Twelve trends and tasks from Electricity 2030

Trends	Tasks
The system is shaped by the intermittent generation of electricity from wind and sun	Make the electricity system more flexible
There is a significant decline in the use of fossil fuels in the power plant fleet	Reduce carbon emissions reliably, shape structural change
The electricity markets are becoming more European	Integrate European electricity markets and make them more flexible
Guaranteeing security of supply within the European internal market	Evaluate security of supply on a European level, develop common instruments
Electricity is being used much more efficiently	Strengthen incentives for using electricity efficiently
Sector coupling: the heating sector, cars and industry use more and more renewable electricity instead of fossil fuels	Improve competitive conditions for renewable electricity in the heating and transport sectors
Modern co-generation* plants produce residual electricity and contribute to energy transition in the heating sector	Provide incentives for modern co-generation systems
Biomass is being increasingly used in transport and industry	Provide incentives in such a way that biomass is used more in transport and industry
Well-developed grid infrastructures create flexibility at a low cost	Expand the grid in a timely, needs-based and cost-effective way
The system remains stable even with high shares of renewable energy	Continue to develop and co-ordinate measures and processes for system stabilisation
Grid financing is fair and meets the needs of the system	Continue to develop regulations for grid charges
The energy sector is using the opportunities offered by digitalisation	Roll out smart metering, build communication platforms, guarantee system security

* *Co-generation* refers to the combined production of heat and power.

Source: BMWi (2019a), "Putting policies in place for an electricity supply that is fit for the future: The 'Electricity 2030' discussion process".

Balancing reforms

German TSOs have led the charge on cross-border co-operation on balancing services. In order to use as little balancing energy as possible, since 2010, the four German TSOs have worked together in the context of the Grid Control Co-operation (GCC). Since 2011, TSOs from Austria, Belgium, the Czech Republic, Denmark, France, Germany, the Netherlands and Switzerland have implemented a cross-border, regional imbalance netting process under the International Grid Control Co-operation (IGCC) (ENTSO-E, 2019). Since 2012, the TSOs of Austria, Belgium, France, Germany, the Netherlands and Switzerland also began a common procurement of frequency containment reserves. Since

November 2017, the Guideline on Electricity Balancing has required all TSOs to develop common platforms for the procurement of automatic and manual frequency restoration reserves and replacement reserves. The mandatory platforms replaced the voluntary mechanisms implemented in 2011 and 2012. The IGCC was chosen by the European Network of Transmission System Operators for Electricity (ENTSO-E) to be the future European platform for the imbalance netting process.

In 2017, the Bundesnetzagentur pursued changes to the design of balancing energy procurement to support the growth in renewable energy, which took effect in February 2018. The Bundesnetzagentur changed the automatic frequency restoration reserve procurement from weekly to daily auctions and adjusted the period of delivering energy to four hours. Given that wind and solar generators need close to real-time forecasts to decide whether to participate in the balancing market, the reforms are expected to benefit variable renewables. It also changed the manual frequency restoration reserve from workday auctions to daily auctions, while preserving the four-hour duration. Lastly, the Bundesnetzagentur also lowered the minimum capacity for participation from 5 MW to 1 MW, supporting smaller renewables installations.

Monitoring, data and transparency

Under the Energy Act and the Competition Act, the Bundesnetzagentur and the Bundeskartellamt are required to conduct joint monitoring activities in the electricity and gas sectors. They publish the results in an annual monitoring report, which addresses investments in electricity and gas infrastructure in recent years as well as the level of competition in the market.

In 2017, the Bundesnetzagentur launched Electricity Market Data (SMARD) (www.smard.de/en/), an online information platform for the electricity market that boosted the transparency of power market data, which is available at close to real time. The database includes information (also in English) on electricity supply, demand, wholesale prices, imports, exports and balancing (BMWi, 2019b).

The government in July 2017 also enacted the Core Energy Market Data Register Ordinance, which called for the Bundesnetzagentur to operate an online database to improve data collection and transparency. In response, the Bundesnetzagentur launched a core energy market data register, the MaStR web portal (www.markstammdatenregister.de), in January 2019, which is open to all market players and the public. The register covers all generation installations and some consumption facilities. The ordinance streamlined bureaucratic reporting requirements to improve data collection.

Energiewende in the electricity sector

Germany's strategy to achieve the goals of its Energiewende, as embodied in the 2010 Energy Concept, can be broadly classified as cutting energy consumption and increasing the share of renewables. For the electricity sector, this includes phasing out other forms of generation, lowering overall electricity demand (though a shift towards electrification in transport and heating can offset the effects of efficiency and demand-side management measures), and increasing the amount of power generation from renewable sources such as wind and solar.

Renewables

As a core plank of the Energiewende, Germany plans to significantly expand the role of renewables in electricity generation, and has already made notable progress in this direction (see Chapter 5 on renewables). Specifically, the country aims for renewables to account for 35% of gross electricity consumption by 2020. Following this, as part of the 2010 Energy Concept, the German government will seek to increase the share of renewables in electricity to 50% by 2030, 65% by 2040 and 80% by 2050. According to the new coalition agreement of March 2018, however, the government is planning to speed up the growth, to reach a share of 65% renewable electricity by 2030.

The Renewable Energy Sources Act (EEG) is the central instrument for the expansion of renewable energy in the electricity sector. The EEG's first iteration, introduced in April 2000, established guaranteed grid connectivity for renewables, preferential dispatch and FiTs for 20 years based on project size and technology.

An EEG surcharge on electricity consumers finances the subsidy for renewables, though energy-intensive industries receive exemptions from the charge. The EEG surcharge covers payments to renewables generators, which reflect the difference between guaranteed payments to renewable installations (either the former FiT or the auction price) and the average wholesale trading price for electricity. As a result, German households pay the second-highest price for electricity among all IEA member countries, at USD 353/MWh in 2018. Levies, charges and taxes, including the EEG surcharge, accounted for roughly half of the total price; the surcharge amounted to EUR 6.792 cents per kilowatt hour (kWh) in 2018, or about EUR 238 for the average household consuming 3 500 kWh of electricity (Bundesnetzagentur, 2018a).

As the costs of FiTs escalated, reforms to the Renewable Energy Sources Act 2014 stipulated that the level of financial support for renewables be set by auction in a competitive framework by 2017 at the latest.

The Renewable Energy Sources Act 2017 created a paradigm shift in renewable energy funding towards more competition and greater cost efficiency, ending the previous system of fixed funding rates, which became too costly and less necessary, as costs for deployment of wind and solar came down rapidly. The most important renewable energy sources – onshore and offshore wind energy, large photovoltaic systems and biomass – are now required to compete in auctions, where only the cheapest offers are awarded contracts.

The costs of the EEG subsidy are beginning to fall as competitive auctions have lowered payments to renewable energy sources. However, as Germany looks towards meeting its ambitious targets for renewables in electricity generation, additional renewables capacity will be required, especially wind generation.

Despite historically strong growth in onshore wind, Germany is now facing a marked slowdown in new onshore wind facilities. Europe's wind energy industry organisation, WindEurope, warned that growth in Germany's onshore wind installations fell to only 134 megawatts (MW) in the first quarter of 2019, its lowest level since 2000 (Deign, 2019). Mounting local opposition to the siting of wind farms is partly to blame. Moreover, undersubscribed auctions have also in part been caused by delays in securing permits. The German wind energy industry association, Bundesverband WindEnergie, estimated that permits could take up to 300 days. Moreover, projects continue to face community opposition that can create impediments to construction timelines even after permits are issued.

Nuclear phase-out

In 2002, the government decided to phase out the use of nuclear power after existing nuclear power plants reach the end of their initial permits (see Chapter 11 on nuclear). Following the 2009 parliamentary election, the federal government adopted a modified energy policy that included the idea to use nuclear energy as a "bridging technology" towards more renewable generation. Accordingly, the government extended the operational lifetimes of nuclear power plants by an average of 12 years under the 11th Act Amending the Atomic Energy Act, which entered into force in December 2010.

However, following the Fukushima Daiichi nuclear accident in Japan in March 2011, the German government decided to accelerate the phase-out of nuclear power through the enactment of the 13th Act Amending the Atomic Energy Act, which entered into force in August 2011. The 13th Act Amending the Atomic Energy Act revoked the additional residual electricity volumes that had been allocated to each operating nuclear power plant in December 2010 under the 11th Act Amending the Atomic Energy Act. In addition, licences for each operating nuclear plant were limited so that all facilities would close by the end of 2022 at the latest. The 16th Act Amending the Atomic Energy Act provides for financial settlement to nuclear plant operators as determined by the Federal Constitutional Court.

Coal phase-out

As the next step in its energy transition, Germany intends to phase out coal-based power (see Chapter 9 on coal). To reach a broad social consensus on the coal phase-out plan, the federal government established a Commission on Growth, Structural Change and Employment in June 2018. It brought together representatives of environmental associations, scientists, trade unions, economic and energy associations, and representatives from the affected regions. The commission presented its report in January 2019, with a recommendation to completely phase out of coal power by 2038. If conditions allow, the phase-out could be brought forward to 2035, an option to be assessed by 2032. As sub-targets, the commission recommended decommissioning 12.5 GW of coal-fired power plants by 2022 and 25.6 GW by 2030. Furthermore, the commission proposed that coal mining regions, coal miners, end users and coal plant owners receive billions of euros in transitional assistance. The government is in the process of formulating legislation that reflects the proposals of the commission. In May 2019, the government approved EUR 40 billion in transitional economic assistance to affected regions, per the commission's recommendations (Buck, 2019).

Co-generation

As part of its decarbonisation efforts and moves to improve energy efficiency, Germany also plans to expand the role of co-generation facilities, with a target to increase the share of co-generation in total power generation to 25% by 2020 (compared with 20% at present). Since 2002, the Combined Heat and Power (CHP) Act has provided support for co-generation through a bonus payment on sold electricity (though the subsidy is more pertinent for industrial co-generation rather than district heating) (BMWi, 2019b). The act was revised in 2016, with funding extended up to 2022. Revisions also included targeted support to gas-fired co-generation facilities to reduce emissions as well as focused funding for boosting flexibility to accommodate rising shares of renewables on power grids.

Additional amendments to the CHP Act were passed in 2017 to ensure that the support framework was consistent with EU state aid rules. In particular, since the end of 2017, support for investment in co-generation plants with capacities of 1 MW to 50 MW has been determined by auction (in a similar manner to the support for renewables). For highly innovative co-generation systems, the government held a separate auction to provide stronger incentives to more flexible, lower-emissions co-generation plants deriving heat from renewable sources.

Smart meters

In 2016, the federal parliament passed the Act on the Digitalisation of the Energiewende, which stipulates the installation of smart meters as well as their technical requirements. The act calls for a phased roll-out of smart meters, with larger consumers and generation facilities slated to be the targets of the first stage. Specifically, consumers with energy consumption of more than 6 000 kWh per year (the average German household consumes around 3 500 kWh per year) and generators of more than 7 000 kilowatts of annual capacity are slated to be fitted with smart meters by 2020. The smart metering infrastructure buildout is referred to as the Smart Meter Gateway.

Data security has been a paramount concern related to smart meters in Germany, prompting the Bundestag to include the most stringent data protection rules in Europe as part of the Act on the Digitalisation of the Energiewende. As smart grids are critical infrastructure, the act required their certification by the Federal Office for Information Security (BSI), which issued its first certificate in December 2018. Mandatory deployment can begin after three manufacturers of smart meters receive certifications (currently eight applications are under review). As such, the roll-out of smart meters has so far been slowed down by delays in technology development and certifications for technology.

In 2016, the government launched the Energy-Savings Meter pilot programme to facilitate the development of digital metering systems. Under this programme, the Federal Office for Economic Affairs and Export Control (BAFA) provides up to EUR 1 million in funding per project to companies that provide customers with metering infrastructure, energy data and advice on energy savings.

Transmission and distribution

In Germany, 80% of the 1.8 million kilometres (km) of electric cables run underground, a relatively high level by international standards, which has helped ensure power supply with minimal interruptions. Looking ahead, though, Germany's energy transition will require more robust grid infrastructure to support the integration of larger volumes of variable renewable energy. Lack of sufficient grid capacity could set back Germany's ability to meet its renewables targets, and/or create more "loop flows" in neighbouring countries.

Existing connections to carry wind power from north to west and south are insufficient to accommodate the increase in renewable energy needed to meet the country's targets. Public opposition to north-south high-voltage transmission lines has forced costlier underground construction of such lines, and public opposition remains an impediment to siting of necessary infrastructure. Due to delays in grid expansion, congestion management measures such as re-dispatch and curtailment of renewable generation are required, which could threaten the expansion of wind power in the north of Germany.

By way of example, in March 2018, Thüringen's premier threatened legal action against the SuedLink transmission line that ran through the state, pushing instead for a route through the neighbouring state of Hessen, which opposed the plan; the opposition of Hessen was backed by Bundesnetzagentur. The disagreements risk further delays to permitting and construction of cross-state transmission infrastructure.

The Thüringer Strombrücke transmission line came into service in 2017, connecting Saxony-Anhalt and southern Germany, which provided some relief and lower re-dispatch costs for 50Hertz's grid zone in the country's east. However, significant levels of congestion remain and will increase the bill for re-dispatch and curtailment measures until significant new grid capacity is brought into service.

The European Commission has threatened to split the German power market into two market bidding zones by 2025 to address the grid bottlenecks between the north and south of Germany. The German government, however, would prefer to maintain a single market and has resolved to address the grid challenges by 2025. In the meanwhile, the German and Austrian governments reached an agreement on a congestion management scheme for the cross-border flow of electricity starting on 28 September 2018, splitting the common bidding zone into two (with at least 4.9 GW of transit capacity maintained between the two countries) (Bundesnetzagentur, 2017).

Measures to address grid congestion

The government recognises that an expansion of the ultra-high voltage electricity grid is essential to shift towards an energy system predominantly based on renewables. In fact, the coalition target to source 65% of power from renewables by 2030 is conditioned on a complementary build-out of the grid. As such, grid expansion is a stated priority for the government. Therefore, 7,700 km of transmission grid expansion measures, including four major north-south high-voltage, direct current (HVDC) lines, have already been adopted into law.

Public acceptance is a central element for the success of the Energiewende, and some transmission projects have run into local opposition. The use of underground cables can help increase acceptance of these projects. This is one reason the federal government ordered the use of HVDC underground cables in 2015 for some projects. A sizeable share of the main north-south lines of the A-Nord, SuedLink and SuedOstLink projects will run underground, driving up costs by an estimated EUR 3 billion to EUR 8 billion (though offset against rising costs for re-dispatch and curtailment).

In 2016, the parliament passed an amendment to the Incentive Regulation Ordinance in order to modernise the regulatory framework for grid investments. In particular, the amendment introduced a capital cost adjustment mechanism to improve the investment environment for grid investments, whereby investment costs can be recognised immediately in grid charges (and the costs are adjusted annually to ensure that consumers benefit regularly from lower capital costs) (BMWi, 2016). Additionally, grid operators that demonstrate high levels of efficiency are compensated with a financial bonus.

More recently, in August 2018, the government published the Electricity Grid Action Plan, which presents a dual-track strategy that includes measures for grid expansion and grid optimisation. Besides accelerating grid expansion through an updated review process, the strategy aims at enhancing the utilisation of existing transmission infrastructure through grid optimisation measures. Following this, in September 2018, the federal government reached a deal on a package of measures with the states (Länder) for a rapid expansion of the grid. The measures include a revision of the Grid Expansion Acceleration Act (NABEG 2.0), agreement on targets for completing planning procedures and forward-looking audits of the process (BMWi, 2018a). The amended Grid Expansion Acceleration Act entered into force in May 2019. The agreement on targets was also reached in May 2019.

The NABEG 2.0 streamlined permitting processes for grid lines, increased the opportunity for public participation during the planning and permitting process, and better co-ordinated the role of the Länder. Changes include fewer permitting requirements for transmission lines along or adjacent to existing routes, allowing a project to begin construction if a regulatory authority is expected to approve it; the establishment of legal deadlines; and the professionalisation of project management functions.

For the end of 2021, the Federal Ministry for Economic Affairs and Energy (BMWi) and the energy ministries of the Länder established the following targets (Netzentwicklungsplan, 2019):

- All projects determined as necessary under the Power Grid Expansion Act (EnLAG) in 2009 are to be permitted by the *Länder*.
- All major north-south transmissions projects are to be approved by the Bundesnetzagentur.
- Half of all expansion projects for standard alternating current (AC) lines under the jurisdiction of the *Länder* must be approved.
- Half of all expansion projects for standard AC lines under the jurisdiction of Bundesnetzagentur have to be approved.

As part of the efforts, the government passed the Federal Requirements Plan Act, which contains a list of priority cross-state projects with the highest national significance, for which special consent procedures will apply. Moreover, the Planning Approval Responsibilities Ordinance was also passed, giving Bundesnetzagentur authorisation to decide on projects of high national significance to further streamline approval processes.

To help determine the transmission grid expansion needs, the government established a streamlined procedure that includes more public involvement than previously (Bundesnetzagentur, 2019b). Every two years, TSOs together draft a Scenario Framework, which undergoes public consultations, following which it requires approval by the Bundesnetzagentur. Based on the approved Scenario Framework, the TSOs jointly determine grid expansion requirements for the next decade. This is again followed by consultations with citizens, industry groups and local authorities. The final Network Development Plan needs to be approved by the Bundesnetzagentur. This plan then informs a list of necessary projects that is submitted by the federal government to parliament at least every four years as a basis for the Federal Requirements Plan. For the Network Development Plan 2019-30, TSOs submitted their first draft in February 2019. After public consultations and Bundesnetzagentur review, the final Network Development Plan 2019-30 is expected to be approved by the end of 2019.

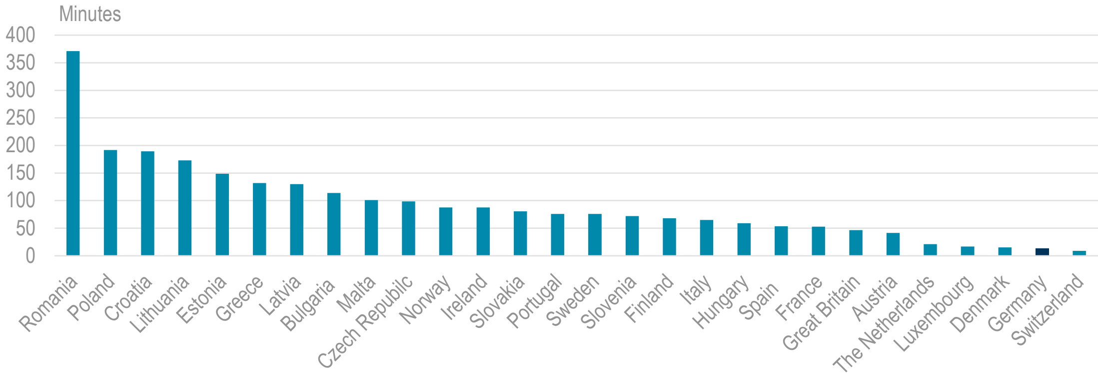
Costs for grid expansions are borne by users, who are required to pay grid charges (subject to a revenue cap for grid operators). As with the EEG, industrial customers receive exemptions, while households pay a larger share. In 2018, grid fees accounted for around 25% of total electricity prices. Under the Grid Charge Modernisation Act that took effect in

July 2017, transmission grid fees will be gradually harmonised across the country by January 2023 in five stages, starting in 2019. The act also phased out payments by network operators to power producers for avoided grid fees, which the government expects to slow down the increase in network costs.

Electricity security

Germany has maintained a high degree of stability in its electricity grid, with minimal disruptions. According to Bundesnetzagentur, the average power outage per customer in 2017 was 15.14 minutes, slightly up from 12.80 in 2016 (Bundesnetzagentur, 2018b). The large share of underground power lines in Germany (80%) helps limit supply disruptions. The rising share of variable renewables in electricity generation has raised concerns about future grid stability, though Bundesnetzagentur finds that extreme weather remains the main driver of power supply disruptions at present. According to a 2018 report from the Council of European Energy Regulators, Germany's electricity security of supply in 2016 ranked second-highest among European countries, after Switzerland.

Figure 7.9 Average annual power supply disruptions in European countries, 2016



Source: Reproduced from CEER (2018) "CEER benchmarking report 6.1, on the continuity of electricity and gas supply".

The government expects it can meet future generation needs after the nuclear and planned coal phase-outs with additional renewables capacity, energy efficiency measures and increased imports (given an estimated 80 GW to 90 GW of overcapacity regionally) (Eckert, 2019). However, Germany's switch from a net exporter of electricity to a net importer will also have implications for regional power generation adequacy. As such, regional co-operation has become a greater focus for the government.

Generation adequacy assessments

Under the Energy Industry Act, the BMWi is required to issue a report every two years on the status of electricity supply security. As stated in BMWi's most recent monitoring report from June 2019, Germany's security of supply would remain high through 2030 compared with international standards, even in a scenario under which the country begins phasing out coal-fired power generation (R2b Energy Consulting et al., 2019). The findings have reinforced the government's belief that sizeable new generation capacity is not needed to meet Germany's medium-term power needs, even in the event of a coal phase-out, especially given cross-border capacity. The latest report switched its methodology for assessing supply security from one based on a simple calculation of maximum consumption against guaranteed supply, to a probability-based assessment under which generation (including imports) can cover load with a 99.94% probability (the probability-based approach is common in many other European countries, and the target model under new EU regulations) (BMWi, 2018b). Some industry organisations have criticised the new approach as too risky, including its reliance on imports (Eckert, 2019).

According to the requirements in the German Regulation on Network Reserve (NetzResV), TSOs are required to undertake an annual system analysis to determine the appropriate power plant reserve capacity needed to ensure grid stabilisation. Bundesnetzagentur then assesses the analysis and publishes its report on the reserve generation capacity requirement each year. In the latest report from April 2019, the winter 2019/20 reserve requirement was 5 126 MW (which can be met with domestic grid reserve plants) and the 2022/23 period requirement was 10 547 MW (not accounting for the planned coal phase-out) (Bundesnetzagentur, 2019c).

Still, on several occasions in June 2019, TSOs reported that the German power grid was severely strained due to insufficient generation, requiring them to call upon “control power” from imports to balance load requirements (Eriksen and Wettengel, 2019). Bundesnetzagentur is investigating the incidents to determine their cause.

Regional co-operation

In order to ensure regional co-operation of electricity security, Germany participates in the Pentalateral Energy Forum (Pentaforum), which is a voluntary co-operation forum among Austria, Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland. Within the Pentaforum, there is a separate working group focused on electricity supply issues. The first assessment of the working group, focused on regional adequacy, was released in 2015 and updated again in 2018. In 2017, the Pentaforum decided to also look at risk preparedness with an eye towards risk preparedness regulation as part of the EU Clean Energy for All Europeans package. To this end, the Pentaforum members conducted a joint regional crisis exercise in 2018 to facilitate the exchange of information during crises.

The most recent assessment by TSOs as part of the Generation Adequacy Assessment under the Pentaforum was published in January 2018. The report found that the probability of German electricity demand being covered by supply is nearly 100% at all times over the reporting period 2018-19 through 2023-24. The TSOs ran 680 different scenarios to arrive at their conclusions, including accounting for extreme weather events. The report confirms the findings of the *Mid-term Adequacy Forecast 2017* conducted by ENTSO-E.

As part of the Clean Energy for All Europeans package, member states agreed to a co-ordinated approach on risk preparedness and response. In particular, member states will be required to put in place the necessary tools to prevent, prepare for and manage possible crises. It also establishes common methodologies for identifying and assessing crisis situations as well as seasonal adequacy based on generation capacity and consumption patterns to preserve grid stability and prevent shortages.

Assessment

Germany has very ambitious energy and climate targets and goals. Targets are defined for renewables, energy consumption, carbon emissions and the renewables share in electricity. The renewables share in electricity has increased impressively over the last years; however, more renewables are needed to meet the goals.

All nuclear capacity will be phased out by the end of 2022 (9 GW) and coal is expected to gradually be phased out by 2038 (12.5 GW already by 2022). As there is currently excess generation capacity, and the government has a target to decrease overall energy consumption, it is yet unclear how much and where new capacity will need to be installed to replace the capacity that will be phased out. Given the environmental and climate goals of the government, it is most likely that renewable capacity will need to be added to the generation mix to replace capacity closures. The phase-out of nuclear power production seems to be well on track, while the government still has to make a formal decision how the phase-out of coal will be implemented.

The phase-out of nuclear and coal can change the supply-side competitiveness of the wholesale electricity market. The remaining dispatchable thermal capacity could end up being concentrated in only a few companies, giving them market power and requiring extra attention from the Bundeskartellamt. Moreover, Germany will likely increase its dependence on natural gas for peak power generation, which will increasingly tie its electricity security to gas security.

The consumer price for electricity contains many charges, levies and taxes; the price of the commodity is less than 25% of the retail price consumers pay. The renewable energy surcharge (EEG-Umlage) is part of the electricity surcharges and is imposed only on electricity consumption and not on other types of energy. The growing share of renewables in electricity makes electrification a way to decarbonise energy consumption in different sectors, e.g. through a switch from heating oil to heat pumps in the heating sector or through a switch to e-mobility in the transportation sector. However, the high consumer price of electricity is working against this, specifically in the heating sector, as the traditional fuels in this sector are subject to lower levies.

This price distortion already exists today, so any funding of subsidies for new renewable electricity capacity through a further increase of the renewable energy surcharge on electricity will raise the relative price of electricity to final consumers even more, and further hinder decarbonisation through penetration of electricity in heating and transport.

Over the last decade, Germany has deployed a large capacity of variable renewable electricity – notably wind – in the north of the country, while electricity consumption is concentrated in the west and in the south of the country. At the same time, the transmission grid has not yet expanded sufficiently to keep pace with this development, creating bottlenecks in Germany and loop flows in neighbouring countries. To overcome this unsustainable situation, multiple strategies need to be followed. The transmission grid needs to be further upgraded and expanded. This includes both more power lines within Germany and more interconnectors to other countries. Germany has, among other things, planned to build four major north-south transmission lines in the country, but these plans face public opposition, and construction has been delayed. New planning procedures entered into force in May 2019, which will help streamline planning and siting processes, so lead times can be shortened considerably. In addition, continued attention to the longer-term needs for grid expansions is needed.

Germany is at the heart of the European power market, which is now coupled and integrated with many European countries, including the Nordic and Baltic countries. Interconnections with neighbouring countries have been constructed over the last years and more will need to follow in the future. Germany should take full advantage of these interconnections in both the wholesale market and the market for balancing services through further integration with neighbouring electricity markets.

Time and locational differentiated price signals are needed within Germany to cost-effectively integrate rising amounts of variable renewable electricity. Opportunities to use EVs and heat pumps to stabilise the electricity system through smart charging and power-to-grid technologies should be explored.

Germany has adopted an energy-only strategy for its electricity market design. Following an extensive Green Paper and White Paper consultation process, the German government took the decision to gradually eliminate price distortions in the electricity market regulatory framework and strengthen price signals. The passage of the Act on the Further Development of the Electricity Market in 2016 established a guarantee against the regulation of wholesale prices and established the strict separation of capacity reserves to avoid distorting wholesale price signals, as these reserves can be used only as a backup measure. This was an important reform needed to allow the investments in renewable and flexible sources to be driven by market signals of wholesale prices, renewable energy auctions, and the EU Emission Trading Scheme carbon price.

In order to further develop a well-functioning and competitive electricity market, both producers and consumers must be exposed to the real-time market prices to the largest possible extent. Germany has taken many steps in this direction. However, there is still room for improvement. On the demand side, smart meters are essential to allow electricity consumers to respond to and benefit from real-time electricity prices. It is important that aggregators, DSOs and other actors in the electricity market can use data from the smart meters, while ensuring that cybersecurity protection and privacy are provided for electricity consumers at the same time.

Renewable energy technologies can provide ancillary services, but this may require regulatory reforms. Balancing markets need to be improved in order to better incorporate renewables. Since July 2018, bids for secondary reserve power are carried out on a daily basis, which brings them into closer alignment with weather and wind resource forecasts. Moving contracts closer to delivery will allow network operators to take advantage of renewables to provide additional balancing services and renewable producers to become part of the solution addressing variability of supply.

In order to use as little balancing energy as possible, since 1 May 2010, the four German transmission system operators have worked together in the context of the GCC. This balancing within the GCC saves control energy and therefore overall costs. In addition, in the past few years, the GCC was continuously expanded beyond the borders of Germany. Now Austria, Belgium, the Czech Republic, France, Denmark, the Netherlands and Switzerland are also members of the IGCC. This allows for the development of international markets for balancing services and to tap cross-border netting potential.

There are approximately 800 DSOs in Germany, and most of them have less than 100 000 customers; the smaller DSOs have around 30 000 customers on average. The small size of many German DSOs can make it difficult for them to reap economies of scale and introduce digitalisation of the grid, needed for a flexible interaction of supply and demand. Moreover, network charges, for instance, are regulated in a way that does not allow for time-of-use network charges. More flexibility in the way network charges can be set could raise possibilities for more cost-effective network operation. Network charges could, for example, encourage flexible demand, raise utilisation of distribution networks and decrease average grid costs.

In the electricity retail sector, switching rates have increased for both households and non-households consumers. However, the majority of German households are still served by their default supplier (under either default contracts or other contracts). Raising awareness among households about the benefits stemming from switching electricity supplier and/or contract types should be pursued.

Recommendations

The government of Germany should:

- Revise taxes and levies imposed on electricity so that consumer prices for electricity do not counter the energy transition by becoming an obstacle to electrification, decarbonisation and further increases of renewables share in total energy supply.
- Ensure the timely build-out and upgrading of transmission lines in order to improve system operations and integrate larger amounts of variable renewable electricity. Consolidate the process of permitting and building new transmission lines to meet future transmission needs.
- Further develop market regulation and digitalisation to expose electricity producers and consumers to real-time market prices of electricity to promote flexibility of supply and demand. Further integrate both wholesale and balancing markets with neighbouring electricity systems.
- Enable regulators to incentivise DSOs to realise economies of scale, set cost-reflective charges and expand distribution grids in a cost-effective way.

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8. Natural gas

Key data

(2018 provisional)

Domestic production: 6.4 bcm (4.7 Mtoe), -64% since 2008

Net imports: 88.7 bcm (121.4 bcm imports, 32.7 bcm exports)

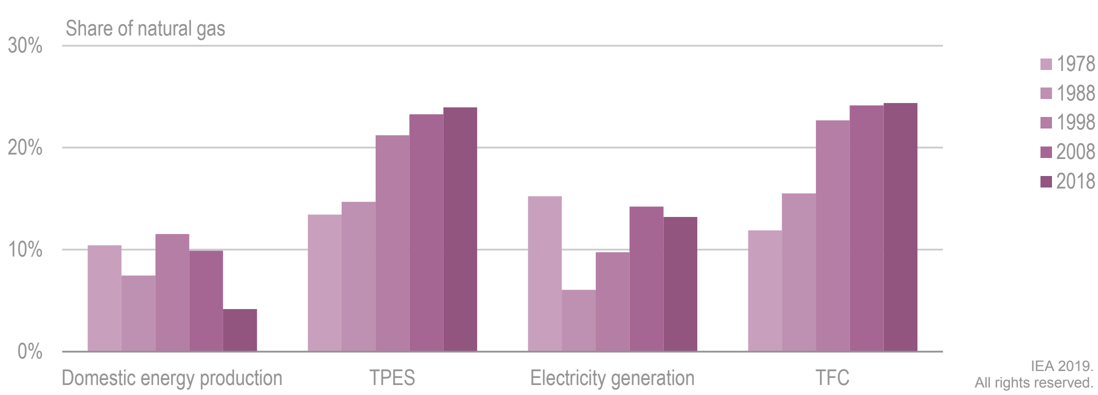
Share of gas: 24.0% of TPES, 13.2% of electricity generation, 24.4% of TFC (2017)

Gas consumption by sector (2017): industry 30.6%, residential 28.8%, heat and power generation 24.4%, commercial 13.8%, other energy 1.8%, transport 0.6%.

Overview

Natural gas is the second-largest energy source in Germany after oil. It accounts for close to a quarter of both total primary energy supply (TPES) and total final consumption (TFC). Natural gas is also the third-largest power source with 13% of total electricity generation in 2018 (Figure 8.1). Domestic natural gas production has declined in the last decade and Germany depends on imports, most of which come from the Russian Federation (hereafter "Russia") and the Netherlands. As European gas production is declining, Germany is looking at alternative sources to secure the long-term gas supply, including liquefied natural gas (LNG).

Figure 8.1 Share of natural gas in the German energy system, 1978-2018



Natural gas is the second-largest energy source (after oil) with nearly 25% of TPES and TFC, but the share of gas has stabilised and the share of gas in domestic production is falling.

Notes: 2018 data are provisional. Latest data for TFC are for 2017.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

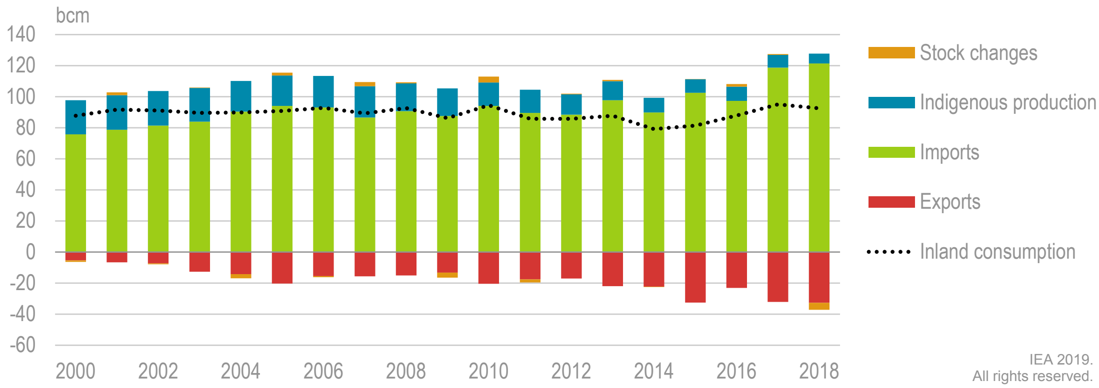
Natural gas is a fossil fuel but can still play an important role in the energy transition, both in power generation and in other sectors. Gas power has struggled to compete against generation from coal-fired plants and renewables, but as the share of variable wind and solar power keeps increasing, the flexibility of gas power generation will become more valuable to the electricity system. Moreover, the planned phase-outs of nuclear and coal power will increase the role of gas in Germany's electricity system. Gas can also replace oil fuels in the transport sector as a way to reduce carbon dioxide (CO_2) emissions as well as local particulate emissions.

Furthermore, Germany is a large producer of biogas, which has been supported by a feed-in tariff (FiT) when used in power generation. Biogas can also be upgraded to natural gas quality to be used as a transport fuel or to replace fossil gas in industry and residential applications (biomethane).

Supply and demand

Domestic natural gas production has declined significantly in Germany in the last decade. From a steady level of over 20 billion cubic metres (bcm) per year until 2007, gas production fell to 6.4 bcm in 2018 (Figure 8.2). This accounted for only 7% of total gas supply, with imports covering the rest. Total net imports increased by 31% between 2014 and 2017, to cover for the drop in domestic production as well as increased demand.

Figure 8.2 Natural gas supply by source, 2000-18



Germany's natural gas production is small and decreasing, and most gas is imported.

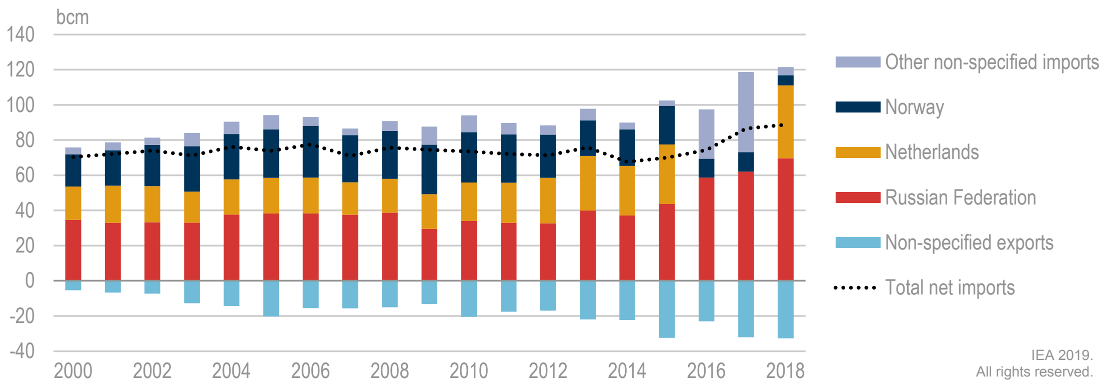
Note: 2018 data are provisional.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

Russia is the largest gas exporter to Germany, accounting for 57% of total imports in 2018, followed by the Netherlands with 34% and Norway with 5% (Figure 8.3). Some of the imported gas is re-exported. In 2018, total imports were 121.4 bcm and total exports 32.7 bcm, resulting in total net imports of 88.7 bcm consumed on the German market.

Germany is the largest natural gas market in Europe, and gas consumption has increased in recent years after a previous drop. In 2017, gas consumption peaked at 95 bcm, just above the previous record from 2010 and 20% higher than in 2014 (Figure 8.4). In 2018, gas consumption remained at a high level but fell slightly to 91 bcm. The recent growth in gas consumption came from a combination of increased demand in the residential sector, industry, and heat and power generation (especially in light of nuclear power plant closures) – the three largest gas-consuming sectors in Germany. The use of natural gas in transportation is currently limited, with around 0.2% of gas used for transport.

Figure 8.3 Germany's natural gas net imports by country, 2000-18

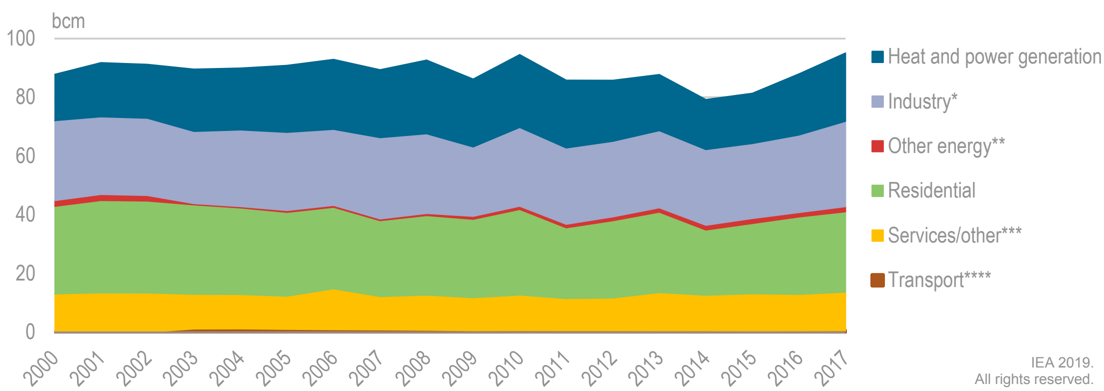


Russia is the largest supplier of gas to Germany, followed by the Netherlands; total net imports increased by 31% from 2014 to 2018.

Note: 2018 data are provisional.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

Figure 8.4 Natural gas consumption by sector, 2000-17



Natural gas consumption increased by 20% between 2014 and 2017, mainly from growing demand in the residential sector, in industry, and for heat and power generation.

*Includes non-energy use.

**Includes oil and gas extraction, refineries, coal mining, and distribution losses.

***Includes commercial and public services, agriculture, forestry and fishing.

****Not visible on this scale.

Note: 2018 data are provisional.

Source: IEA (2019b), *Natural Gas Information 2019*, www.iea.org/statistics/.

The industry sector accounts for the largest gas consumption in Germany, with over 30% of the total. Around 10% of this is for non-energy purposes in the chemical and petrochemical sector, which is also the largest gas-consuming industry overall. Natural gas consumption in industry increased by 13% from 2014, mainly in the chemical industry.

Residential gas demand has decreased from peak levels in the early 2000s, when it accounted for over a third of total gas consumption. However, it increased significantly in recent years with 23% growth from 2014 to 2017. The gas is mainly used for heating purposes, and consumption varies with temperature variations. Residential gas demand generally peaks in the winter months and can be up to three times higher than summer demand. Meanwhile, commercial gas demand has been fluctuating within the range of 11 bcm to 13 bcm over the past decade.

The third-largest gas consumer is power and heat generation. Gas used in power generation decreased by 31% from 2010 to 2014 as it struggled to compete against new renewables and cheap coal power. This trend has shifted in recent years as gas consumption in the heat and power sector increased by 37% from 2014 to 2017, especially in light of closures of nuclear power plants. In 2018, gas power plants generated 85 terawatt-hours (TWh) of electricity, which accounted for 13% of total power generation.

Looking ahead, the closure of all nuclear generation by the end of the 2022 and the planned phase-out of coal-fired generation over the next two decades is expected to increase the call on gas-fired generation to meet power sector load needs (though efficiency measures might offset some of the demand growth, as will growth in renewables). The government anticipates that gas consumption in electricity will grow over the coming years, while gas consumption in the heating sector will fall, overall resulting in net growth in gas demand as well as imports.

Institutions

At the federal level, under the Energy Industry Act (EnWG) from 2005, Germany's electricity and gas markets are regulated by the Federal Network Agency (Bundesnetzagentur). The primary responsibility of the agency is to ensure fair and effective competition in the supply of gas (and electricity), including by establishing non-discriminatory third-party access to networks and monitoring prices (Bundesnetzagentur, 2019). In particular, the Bundesnetzagentur oversees network operators whose network reaches over 100 000 customers (directly and indirectly) or crosses state borders. All networks not covered by the Bundesnetzagentur fall under the regulatory jurisdiction of the states (*Länder*). In collaboration with the Bundesnetzagentur, the *Länder* and the Bundeskartellamt oversee competition in the gas and electricity sectors, based on authority under the Act Against Restraints of Competition. The agencies issue a monitoring report on the gas sector (along with the electricity sector) each year.

The Federal Ministry for Economic Affairs and Energy (BMWi) is also the lead agency with respect to natural gas security and has the authority to intervene in situations where standard market-based measures are insufficient. It is responsible for the co-ordination and implementation of emergency response measures at the national and European Union (EU) levels. Additionally, once the emergency level is declared, the Bundesnetzagentur becomes the federal load distributor. This means the Bundesnetzagentur has to ensure the distribution of gas for covering the vital needs of energy consumption. All responsibilities and measures to this end are outlined in the National Emergency Plan for Gas, which is published by the BMWi.

Upstream policy

Germany's oil and natural gas fields are primarily located in the country's north, with around 90% of gas production and reserves located in the federal state of Lower Saxony (Lang and Lind, 2018). Germany's two offshore oil and gas fields are situated in the North Sea. Though some domestic gas is produced through conventional fracking methods, Germany has had a ban on unconventional fracking since 2017. At the same time, it also restricted the use of conventional fracking, especially in sensitive ecological areas.

The Federal Mining Act of 1980 set out the regulatory framework for oil and gas exploration and production (E&P). The act was modified under the Federal General Mining Ordinance of 1995 to bring it in line with EU laws (Lang and Lind, 2018). The federal states under which E&P activity takes place issue licences.

Market structure

The German gas market is characterised by a large number of privately organised companies operating in the areas of networks, storage and gas trading. Since 2011, there are two market areas – or balancing zones – in Germany: NetConnect Germany (NGC) in western and southern Germany and Gaspool in northern and eastern Germany. Each area has its own co-ordinator who ensures that access to the gas grid and market activities are carried out in an efficient fashion. The two market areas are down from 19 such areas in 2006, indicating a significant degree of consolidation, which has improved market liquidity. In 2017, the German Gas Network Access Ordinance announced that NCG and Gaspool would be required to merge their market areas no later than 1 April 2022. As a result, the two gas market areas will be combined into a single nationwide market area from 1 October 2021.

There are currently 16 gas transmission system operators (TSOs) in Germany, a large number by European standards. Other players are the distribution system operators (DSOs), storage facility operators and commercial enterprises. The EU internal market package for the liberalisation of the market for electricity and natural gas, most recently amended by the Third Internal Energy Market Package, redefines the areas of activity of market players. To promote competition, the operators of gas supply networks are separated from natural gas trading activities. Germany has the most complex gas distribution system in Europe with over 700 operators of regional gas distribution systems and over 800 gas suppliers.

At the retail level, most households (51% in 2017) were supplied by their local default supplier under a non-default contract. Around 19% were under default supply contracts, while households with contracts other than their local default supplier stood at 30% in 2017.

Gas sold to non-household customers is mostly interval-metered. Around 27% of the volume to these end users was with a default supplier on non-default terms, while around 73% was under a contract with a seller that was not the default supplier. For non-households, default supply is more limited and on a declining trend.

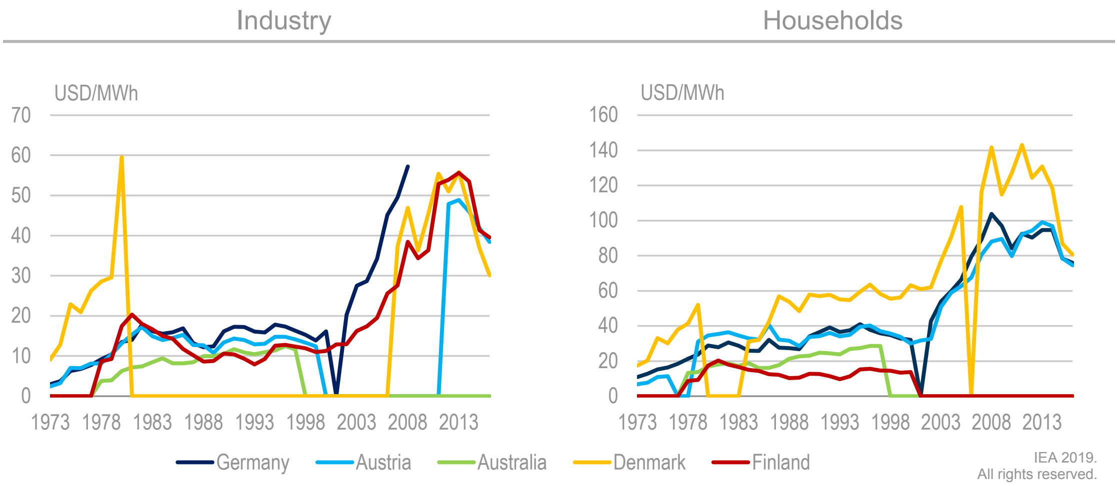
Interruptible contracts are made only with industrial customers that have the capability of fuel switching. Around 10-20% of gas sold to industrial customers is conducted as interruptible contracts.

Prices

Germany's wholesale gas prices are set on its two gas hubs: NCG and Gaspool. Both track relatively closely to prices on Europe's largest gas hub, the Title Transfer Facility (TTF). Wholesale prices are generally marginally higher than TTF prices, but lower than gas prices in Central and Eastern European hubs. Germany's natural gas import prices (border price) over the period January-June 2019 averaged EUR 4.90 per terajoule (BAFA, 2019).

At the retail level, Germany's industry gas price is slightly below the median among International Energy Agency (IEA) member countries, while the residential price is exactly at the median level. Compared with neighbouring countries, Germany's prices are relatively low (Figure 8.5). The German industry prices have followed the same development as in the Netherlands. Household prices have remained at a lower level in Germany while increasing in neighbouring countries in the past few years. Natural gas prices are not regulated in Germany.

Figure 8.5 Natural gas prices in selected IEA member countries, 2000-18



Germany's gas price is below most neighbouring countries for both industry and households.

Notes: MWh = megawatt-hours. Data not available for Germany 2001 and industry for Austria 2000-11 and the Netherlands 2004-06.

Source: IEA (2019c), *Energy Prices and Taxes Third Quarter 2019*, www.iea.org/statistics/.

Germany applies taxes and levies on household consumers of gas at around 15%, higher than the European average of 10%. Similarly, compared with a European average of 10% for industrial consumers, German taxation levels are about 18%.

Infrastructure

Pipelines

Germany's robust gas network covers long-distance, cross-border pipelines from supply sources, as well as local networks for distributing gas to end users. The German gas grid covers a total of 511 000 kilometres (km) (BMWi, 2019a). Germany also serves as an important transit country for gas to other countries in Europe and could become Europe's second-largest gas transit country after the Nord Stream 2 pipeline is constructed (see below).

As Germany's largest source of gas imports, pipeline connectivity to Russia is of paramount importance and served by three main pipeline systems:

- The Yamal-Europe system, with a capacity of 33 bcm, which crosses the German border at Mallnow, where it links to the YAGAL-Nord transmission system. The pipeline crosses through Belarus and Poland.
- Nord Stream, with a total capacity of 55 bcm along two lines. Notably, Nord Stream runs directly from Russia, across the Baltic Sea and into Germany (at Lubmin, near Greifswald), thereby bypassing other transit countries. From Germany, Nord Stream can also supply customers in Belgium, the Czech Republic, Denmark, France, the Netherlands and the United Kingdom.
- The Ukrainian gas transmission system, with a total capacity to transport over 100 bcm from Russia through Ukraine. From Ukraine it can transport around 80 bcm annually to Slovakia, where it can then transit through the Czech Republic to Waidhaus in Germany (and possibly to Brandov and Hora Svate Kateriny), as well as connect to the Yamal-Europe pipeline (Gazprom Export, 2019). Gas can also transit via Austria through Oberkappel. All in all, it is possible to send around 10 bcm of gas to Germany via Ukraine.

Within Europe, Germany has the capacity to receive 54 bcm of gas from Norway to Emden (some of which transits to the Netherlands) and Dornun in northern Germany through three pipelines: Norpipe and Europipe I and II. There are also several pipelines to transport gas from the Netherlands, notably the Groningen gas field, to Germany.

The most significant new pipeline project to bring gas into Germany will be the Nord Stream 2 gas pipeline that will run along the same route as the original Nord Stream pipeline with a capacity of 55 bcm/year (and will significantly increase the amount of gas that does not transit through Ukraine). The pipeline is currently under construction and project developers expect it to be completed by the end of 2019 or early 2020 (Nord Stream 2, 2019).

In line with the European Union's Third Internal Energy Market Package, the EnWG requires gas TSOs to draw up a joint network development plan (NDP) covering the whole of the country in every even year. The plan must include all the technical measures for enhancing, reinforcing and expanding the network in line with requirements and for guaranteeing security of supply over a ten-year horizon. In odd years, the TSOs are required to submit a joint report on implementation of the NDP by 1 April.

TSOs submitted their draft gas NDP for 2018-28 to the Bundesnetzagentur in April 2018, under which they propose 41 expansion measures through 2028, at an investment cost of EUR 7 billion. In total, the TSOs proposed the addition of 1 390 km of pipelines and an increase in the capacity of compressor stations by 499 megawatts (MW). The bulk of the increase compared with the 2016-26 NDP is due to the planned European Gas Pipeline Link (EUGAL), which will transport gas from the planned Nord Stream 2 import pipeline from Russia to other places within Germany, to the Czech Republic, and likely down to Austria. As such, it will run from the Baltic Sea to the German-Czech border. In addition, the latest NDP includes plans to connect a planned new LNG import terminal at Brunsbüttel to the gas grid (see below on LNG).

Several parts of Germany's gas grid are served solely by low-calorific natural gas (L-gas), which can be fed only with indigenous gas or gas imports from the Netherlands. As both domestic and Dutch gas supplies fall further in coming years, Germany will need to rely exclusively on high-calorific gas (H-gas), which makes up the rest of its supply, including from Norway, Denmark and Russia. Given that H-gas cannot be shipped on L-gas networks (or used in the boilers of many end users, which will require adaptation), TSOs and DSOs in 2015 began a process to fully convert the gas grid to H-gas by 2030. In 2015, there were 969 L-gas interconnection points that needed to be converted, compared with 922 in 2017. The states at least partially impacted are Bremen, Hesse, Lower Saxony, North Rhine-Westphalia, Rhineland-Palatinate and Saxony-Anhalt (BMWi, 2019a). The TSOs expect that by 2023, more than 2.5 million gas appliances will have been adapted to H-gas.

Storage

Germany has suitable geological conditions for gas storage facilities. At the end of 2017, Germany had 49 operational gas storage facilities, of which 17 were pore storage and 21 were salt caverns. Based on these facilities, the maximum working gas storage capacity in the country is 24.3 bcm, which could cover 47 days of Germany's 20-year peak demand metric (see emergency response section below). Among EU countries, Germany has the largest natural gas storage capacity, and the fourth-largest in the world.

Table 8.1 Natural gas storage capacity in select countries

	United States	Russia	Ukraine	Germany	Italy	Netherlands	France
Storage capacity (million cubic metres)	128 099	70 400	32 180	24 600	17 112	12 807	12 781

Source: BMWi (2019a), "Gas", www.bmwi.de/Redaktion/EN/Textsammlungen/Energy/gas.html.

Operators of gas storage facilities are required to offer access to other companies on appropriate and non-discriminatory technical and commercial terms. Additional rules on access to storage facilities are governed by EU Regulation 715/2009 related to transparency, as well as voluntary practices under the European Guidelines on Good Practice for Storage System Operators.

LNG

At present, Germany does not have its own LNG regasification terminals. However, the country is looking at options to diversify its gas import sources through LNG. Germany currently has access to LNG, despite not having an LNG terminal, through its regional market integration into the northwestern region that has spare LNG capacity (Rotterdam, Zeebrugge, Dunkerque), with pipeline interconnections to Germany. Spare regasification capacity elsewhere and low transportation costs previously undermined the business case for potential LNG terminals in Germany itself. However, due to the shutdown of Groningen production in the Netherlands by 2022 at the latest, there is renewed interest in LNG investments. There are now investment plans for three German LNG import terminals (Brunsbüttel, Stade, Wilhelmshaven) and one small-scale terminal (Rostock). The government intends to offer financial support for LNG investments within the framework of the Joint Federal/Länder Task for the Improvement of Regional Economic Structures and its support programme for alternative fuels. In addition, the cabinet in March 2019 agreed on a regulatory reform that requires pipeline operators to shoulder 90% of the cost of network connectivity to new LNG plants, with LNG operators bearing only 10% of the cost.

Figure 8.6 Germany's planned LNG facilities

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international prontiers and boundaries and to the name of any territory, city or area.

Source: Petroleum Economist.

Alternative applications for gas

Natural gas in transport

The German government has recognised the role that natural gas vehicles can play in decarbonising the transport sector as well as reducing air pollution, which is becoming a more salient challenge in German cities (see Chapter 3 on climate change). The government's March 2013 mobility and fuel strategy highlights the role of natural gas in this capacity. In September 2016, the BMWi launched the Round Table on Gas-Based Mobility to recommend measures to achieve a target established in 2015 by the government and the automotive industry to meet 4% of transport fuel needs with natural gas by 2020 (BMWi, 2019a).

The commitment to natural gas as a transport fuel was reaffirmed in the 2018 coalition treaty, which extended tax breaks for natural gas beyond 2018 (VDA, 2019). From July 2018, German subsidies for purchases of natural gas vehicles amount to EUR 8 000 for compressed natural gas (CNG) and EUR 12 000 for LNG (up to EUR 500 000 for a given manufacturer) (NGV Global News, 2018).

Still, the use of natural gas in transportation is currently limited, making up less than 1% of total transport fuels consumption. On the other hand, oil-derived fuels still account for over 94% of transport fuels. Moreover, the government's core focus for decarbonising the transport sector has shifted more to electric vehicles (EVs) and, longer-term, to hydrogen technologies. German automakers are also more focused on EVs, though some also have smaller lines of CNG passenger cars.

The German government is also exploring options to expand the role of LNG in trucking for freight transport, an integral component of Germany's road transport sector. In October 2018, the Bundestag voted to exempt natural gas trucks from highway tolls for two years from 1 January 2019 (NGV Global News, 2018). Still, a sizeable buildout of fuelling infrastructure will need to support uptake of LNG trucks in larger volumes, at the same time that many manufacturers are shifting attention to electric drivetrains for larger vehicles and trucks as well (though battery weight remains a considerable hurdle for long-distance trucking).

Germany's role as an international transport hub and a major export-oriented economy will require additional options for ships to refuel with lower-carbon fuels, especially as more stringent international shipping regulations take effect in 2020. Natural gas has an important role to play here, too. The siting of an LNG import terminal on Germany's coast might help advance LNG for shipping, though additional LNG infrastructure will also be needed to support a more significant buildout of the sector.

Renewable gas

The Renewable Energy Sources Act (EEG) of 2000 first introduced FiTs for renewable power, including power produced from biogas, while subsequent amendments to the act in 2004 and 2009 expanded upon the incentives. As a result, Germany has experienced a surge in biogas facilities since 2008, with around 9 500 plants active in 2019 (Budde and Newman, 2019). However, since changes to the EEG in 2014 shifted the system of payment away from FiTs to competitive auctions, there has been a significant drop in the construction of new biogas facilities, as biogas installations have not seen the dramatic cost reductions experienced by wind and solar power (Appunn, 2016). Still, the opportunities for biomethane,[12] in particular, are increasing as Germany looks towards decarbonising the heat and transport sectors.

Biomethane is considered a medium- to longer-term option for transport and heat due to high production costs at present. Biomethane for these applications has been produced on a small scale; the bulk of current biogas and biomethane production is used in electricity based on the previously mentioned attractive financial incentives. In 2017, biogas and biomethane together generated approximately 32 000 gigawatt-hours (GWh)

[12] While biogas contains other components beyond methane, such as CO_2, and is usually consumed close to its production, biomethane is an upgraded form of biogas that can be substituted for natural gas and transported through gas grids.

of electricity, or around 5.4% of gross electricity consumption. In contrast, they accounted for just 0.5% of final consumption in heating and 0.1% in transport.

In late February 2019, the BMWi alongside the German Energy Agency (Dena) launched the dialogue process Gas 2030, which is supposed to develop a broader vision for the role of natural gas across government and industry stakeholders. The effort will have a particular focus on the target volume of renewable gas in the energy mix, as well as a strategy on the most efficient ways to integrate renewable gas into the existing energy system. The results of the Gas 2030 dialogue will be published shortly. Based on this process, the ministry plans to formulate its strategy for renewable gas.

Power-to-gas

As Germany continues to shift towards a power grid sourced increasingly by renewables, the government has plans to broaden the use of renewables-based electricity to other sectors through sector coupling. As part of these plans, the government is also focused on power-to-gas and power-to-hydrogen technologies. Given the variability of renewable power sources such as wind and solar, converting electricity from renewables into gas or hydrogen, which can be stored in Germany's existing gas infrastructure (though additional assessments are needed to determine the compatibility for hydrogen), offers an attractive flexibility solution for balancing variability from renewables in the power system. The synthetic gas could also play an important role in decarbonising the heat and transport sectors. Moreover, it can provide a solution for surplus renewables capacity to avoid curtailment.

At present, power-to-gas projects lose a considerable amount of energy in the conversion process, making them relatively expensive and inefficient. To advance the technology, Germany has supported the research, development and demonstration of converting electricity produced by renewable sources to natural gas. The potential of power-to-gas projects is partly dependent on cost-effective options to store the gas, making the role of the existing gas grid an essential part of the strategy.

Energy security

Germany has ensured a relatively high level of gas supply security, despite a heavy reliance on imports. According to a monitoring report from the Bundesnetzagentur and the Bundeskartellamt, the average interruption in gas supply per connected final consumer was 0.99 minutes in 2017 (Bundesnetzagentur and Bundeskartellamt, 2018). Under Section 51 of the EnWG, the BMWi is tasked with monitoring the security of the grid-based supply of natural gas.

In 2015, the BMWi introduced two measures that were designed to improve the security of gas supply in the country: 1) market area managers (MAMs) were allowed to enter into supply contracts for higher volumes of gas, which would be put into a reserve to be called upon during periods of regional disruptions; and 2) a new balancing product was created that allowed large industrial customers to voluntarily reduce demand to boost supply security (BMWi, 2015).

Though the German government is focused on a massive buildout of renewables, the phasing out of both nuclear and coal generation will also increase Germany's demand for natural gas in power generation, including as a backup fuel source for renewables. The uptick in demand will increase Germany's already-high call on imports. Moreover, at the same time that Germany's own production of gas is small and declining, its gas imports from European sources are also set to fall in the coming years, especially from the Netherlands, where production from the Groningen field is declining and due to fully terminate by 2022 at the latest. As a result, security of natural gas supply is a top concern for the government.

Generally speaking, gas providers in Germany ensure security of supply through the following means: 1) diversification of supply sources and routes; 2) stable relationships with supplier countries; 3) long-terms supply contracts (often 20 years or longer); and 4) reliable supply infrastructure, including underground storage (BMWi, 2019a).

Revisions to the Gas Network Access Ordinance, including the reduction of gas market areas from 19 in 2006 to 2 today, boosted liquidity and improved gas supply security (see section on market structure above). In particular, the unification into one zone is expected to be positive for competition and favourable for security of supply by mitigating the market power of any one market participant.

Gas supply diversification is an important component of Germany's energy security strategy. Though Germany has strong pipeline connectivity to several sources, Russia remains a dominant supplier. Moreover, the completion of the Nord Stream 2 pipeline could further increase Germany's reliance on Russian gas imports (though will mitigate the risk of potential supply disruptions on transit routes).

To mitigate risks associated with dominant pipeline suppliers, Germany is advancing plans to facilitate LNG imports (see above on LNG), which can play an important role in the country's gas security strategy. Transitioning into a gas and renewables system will lead to lower price elasticity for gas (the gas will be needed at whatever price when the wind does not blow), further reinforcing exposure to dominant pricing behaviour. Even though Russia is likely to remain the largest gas supplier to the German market, an LNG terminal could improve Germany's negotiating leverage to secure more favourable import prices.

The federal government also supports infrastructure projects that enable gas to be supplied from the Caspian region to Europe (the Southern Gas Corridor) as a means of improving gas security through diversification (though the gas will not directly enter into Germany).

From a storage perspective, Germany's current capacity can help ensure security of supply during extreme weather or disruption events (see section on storage above). Assuming relatively full levels of existing storage capacity, a 2015 report from the BMWi on possibilities to improve gas security and crisis prevention via regulation of storage reaffirmed the positive role that storage in Germany can play during supply disruptions (Becker Büttner Held, 2015). Nonetheless, storage facilities in Germany, as in other parts of Europe, are facing the threat of closure due to weak economics, which could create gas security risks if the number of closures ramps up.

Emergency response

There are several legal tools available to German authorities for natural gas emergency response. These include ordinances that can be used to restrict the sale, purchase or use of goods, in terms of both quantity and time, or permit them only for certain priority purposes, to ensure that vital energy needs are met. Moreover, Germany closely aligns its gas emergency response strategy with that of the European Union.

The basis for Germany's natural gas emergency response policy is established through several laws and regulations. These include:

- EU Regulation 2017/1938
- EnWG
- Energy Security of Supply Act
- Ordinance to Ensure the Supply of Gas in a Supply Crisis.

The European Union's 2017/1938 regulation defines three crisis levels: early warning, alert and emergency levels. For the first two levels, the regulation lays out market-based measures that gas suppliers can take to mitigate crises. Governments can intervene only in the case of emergencies. The BMWi is the German authority tasked with implementing emergency measures under this regulation, whereas the Bundesnetzagentur is tasked with providing regular risk assessments and updates on natural gas supply security.

The EnWG establishes that market participants are principally responsible for ensuring the security of gas supplies, particularly to protected customers and district heating installations. In general, TSOs and DSOs do so through standard market-based measures such as internal balancing, purchasing external balancing capacity, the redistribution of volumes, load flow commitments and/or interruptible contracts. In the event of a natural gas emergency, certain groups of customers are protected from interruption to their natural gas supplies. Protected customers (which represent around 50-60% of demand) are defined as households and district heating installations delivering heating to households.

Market participants have reinforced co-operative efforts through a formal agreement that outlines contingency planning guidelines. They have also established communication protocol with electricity TSOs. TSOs, MAMs and the Bundesnetzagentur are all required to designate crisis managers who are responsible for taking action during a supply disruption, and for communicating with the BMWi. An interdisciplinary crisis team, made up of the designated crisis managers, would advise and support the BMWi both in advance of and during a crisis. One of the key tasks of this team is to provide a consultative mechanism between relevant stakeholders, ensuring the widespread exchange of essential information.

At the regional level, natural gas emergency policy also involves the *Länder* and municipal energy suppliers. As per the Ordinance to Ensure the Supply of Gas in a Supply Crisis, the responsibility to ensure load distribution would be transferred to the *Länder* and the Bundesnetzagentur as competent state agencies. The *Länder* are responsible for implementing some aspects of non-market-based emergency measures in conjunction with the Bundesnetzagentur.

There are no compulsory natural gas storage requirements in Germany, and no state-owned storage facilities. Operators of gas storage facilities must grant other companies access to their storage facilities and auxiliary services at a fair market price. Having the largest storage capacity in the European Union, Germany also provides flexibility to neighbouring markets (and also uses some storage in neighbouring countries). Storage is therefore crucial not only because of high consumption for heat generation and low flexibility of residential demand during German winters, but it is also essential to regional security of supply.

Germany, as an EU member state, is required to meet the infrastructure standard detailed in Article 5 of the EU Gas Security of Supply Regulation 2017/1938. This relates to the ability to satisfy total gas demand in the event of a disruption of the single largest gas infrastructure, during a day of exceptionally high gas demand occurring with a statistical probability of once in 20 years. The EU infrastructure standard is met where the N-1 value is greater than or equal to 100%. Germany met this infrastructure standard in 2018, with 227%, based on the 20-year peak demand metric of 517.44 million cubic metres (mcm) per day and the 86 mcm/day capacity of the Mallnow connection being the single largest infrastructure within a total transmission network capacity (incoming) of 1.18 bcm/day (BMWi, 2019b).

Assessment

Germany is the largest natural gas market in Europe, and gas made up around 24% of German energy consumption in 2017. Heating and electricity generation are the main drivers of natural gas consumption. Gas currently accounts for 13% of electricity generation and 42% of heating needs. While improvements in energy efficiency and growth in renewables could act as a drag on future gas demand, policies to shift the power mix away from nuclear and coal towards renewables will result in increased demand for natural gas in the power sector in the coming decade. Meanwhile, heating is the largest sectoral demand driver for natural gas, though government policy aims to reduce this level in the coming years. On a net basis, demand for natural gas may grow until around the middle of the next decade, plateau, and then gradually decline thereafter.

Germany remains the largest natural gas importer in Europe. The country must import 92% of its natural gas supply. In 2018, it received 57% of imports from Russia, 34% from the Netherlands and 5% from Norway.

Policy makers are encouraging strategic investments to ensure a diversified and secure supply of gas to meet future demand. Still, security of supply issues bear monitoring. While Germany's own production of gas is small and declining, gas imports from European sources are also set to fall in the coming years, especially from the Netherlands, where production from the Groningen field is declining and due to fully terminate by 2022 at the latest. As such, Germany is seeking to boost gas imports from other sources, including pipeline gas imports from Russia via the Nord Stream 2 pipeline (doubling the 55 bcm capacity of Nord Stream 1) that is expected to enter into service at the end of 2019 or early 2020. Nord Stream 2 will improve Germany's direct access to Russian gas (though Germany also supports gas transit through Ukraine after 2019).

Germany is also looking at options to diversify its gas import sources through LNG. Private investors are currently planning three LNG import terminals on the northern coast, of which at least one is expected to reach a final investment decision in 2019. A terminal would enable Germany to diversify imports further. Germany currently has access to LNG capacity through its European neighbours, where capacity utilisation has been on average below 30%. Though expected low utilisation has undermined the business case for LNG import terminals in Germany to date, declining imports from the Netherlands will help boost the investment case, even if near-term utilisation rates remain relatively low for commercial reasons. Moreover, the LNG import option will give Germany leverage to secure better pricing from other suppliers as well.

The German government is developing a plan to phase out coal-fired power stations; a government-appointed coal commission recommended an exit date of 2038 at the latest, while most coal-fired capacity will already close before 2030. Although policy makers expect that renewable energy will eventually replace most of the lost capacity, maintenance of flexible gas-fired capacity will also be needed in the medium term, as will additional gas-fired generating capacity. Natural gas's share in electricity generation rose from 10% in 2015 to 13% in 2018. Gas has a role in decarbonising energy consumption while providing the reliability needed to compensate for variable renewable generation. Currently, gas generation is facing competitive pressure amid low wholesale electricity prices, so monitoring gas power capacity to avoid excessive closures will become more important in future years.

In 2017, Germany had 49 natural gas storage facilities, with 24.3 bcm of working gas, the equivalent of 47 days of demand at 20-year peak level. This is an increase from 48 facilities with 20.4 bcm metres in 2013. Natural gas stocks in Germany are maintained on a commercial basis to guarantee security of supply, and there are no mandated storage levels. Nonetheless, the government is compliant with the EU Regulation 2017/1938 to meet the N-1 standard in gas security of supply due to infrastructure reliability and substantial storage capacity. Still, as elsewhere in Europe, an uptick in closures of storage facilities based on weak economics warrants watching from a gas security perspective.

The use of natural gas in transportation is currently limited, with around 0.2% of gas used for transport. Oil-derived fuels still account for over 94% of transport fuels. Without further policy support from the government, increased use of gas in transportation is unlikely for commercial reasons, despite the government's desire to decarbonise the transport sector. There is potential growth for natural gas use in maritime bunkering to lower the carbon emissions of Germany's export-oriented economy.

Germany has the most complex gas network in Europe with 16 TSOs, 700 distribution companies and almost 800 gas suppliers, creating a highly competitive market. In addition, in 2017, the German Gas Network Access Ordinance announced that NCG and Gaspool would be required to merge their market areas by 1 April 2022. TSOs and the Bundesnetzagentur have agreed to launch the single market area by 1 October 2021. The planned unification presents an opportunity to further increase liquidity in German gas trading areas. The unification is expected to be positive for competition and favourable for security of supply by mitigating the market power of any one market participant.

Renewable gas is considered a medium- to longer-term option for transport and heat due to high production costs at present. Renewable gas for these applications has been produced on a small scale; the bulk of current biogas and biomethane production is used in electricity based on previous attractive financial incentives. At the end of 2018, the BMWi launched the dialogue process Gas 2030, which is supposed to develop a vision across government and industry stakeholders on the future role of gas. Based on this process, the ministry plans to formulate its strategy for renewable gas.

Germany has supported the research, development and demonstration of converting electricity produced by renewable sources to biomethane. The potential of power-to-gas and power-to-hydrogen projects are partly dependent on cost-effective options to store the gas. The use of existing transmission and distribution networks for natural gas can be further explored to enable greater deployment of renewables.

On gas data collection, as of 2016, all natural gas imports are allocated under "non-specified other" gas imports. The same holds for all gas exports, including traded volumes transiting the country. The IEA also notes that collection of monthly gas data for deliveries to consumers is lacking. Notwithstanding existing data protection legislation, specifying the import and destination countries and consumption categories would ensure data transparency and promote market functioning, especially as Germany is at the centre of gas trading in Europe, and is the largest gas-consuming country in the European Union.

Recommendations

The government of Germany should:

- Strengthen capacities to diversify imports by supporting the buildout of LNG terminals, and facilitate connectivity to the natural gas supply chain.
- Monitor changes in natural gas-fired generation capacity to support its ability to provide complementary flexibility to variable renewables generation.
- Examine strategies for the medium-term development of biogas/biomethane, including an expanded role in the heating and transport sectors, and identify supports needed to use existing natural gas infrastructure in biogas development.
- Encourage wider and more efficient adoption of natural gas as a fuel for transportation applications, such as shipping and trucking, by facilitating the relevant gas supply chain and increasing investment certainty for market players.
- Collect and disseminate annual gas trading data and monthly gas consumption data.

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9. Coal

Key data

(2018 provisional)

Production: 169 Mt/38 Mtoe (2% hard coal, 98% brown coal), -13.1% since 2008

Net imports: 44.2 Mt/28.5 Mtoe

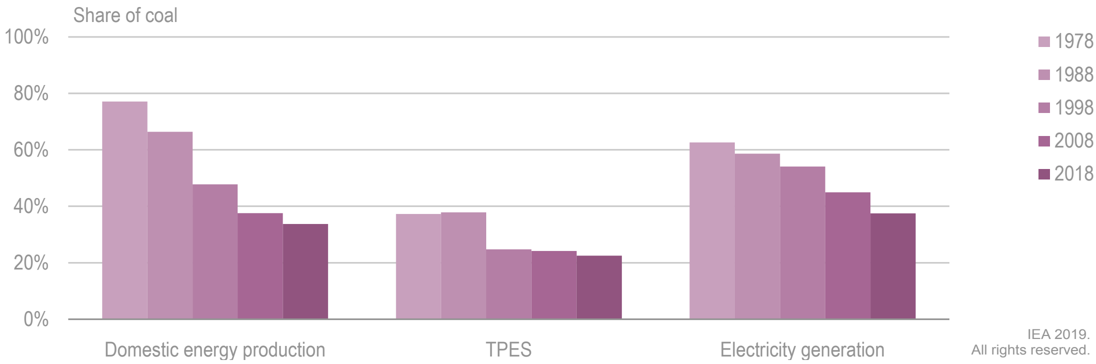
Share of coal: 22.5% of TPES and 37.5% of electricity generation

Consumption by sector (2017): 71.4 Mtoe (heat and power generation 79.2%, other energy 10.7%, industry 9.4%, residential 0.7%)

Overview

Coal is the third-largest source of energy in total primary energy supply (TPES) and is the largest source of electricity production in Germany. It also accounts for 40% of energy-related carbon dioxide (CO_2) emissions. However, the share of coal in energy supplies has been declining steadily for decades, notably in power generation, where it fell from 45% in 2008 to 38% in 2018 (Figure 9.1).

Figure 9.1 Share of coal in different energy supplies, 1978-2018



The use of coal has dropped steadily in the last decades, particularly in electricity generation and domestic energy production.

Notes: 2018 data are provisional.

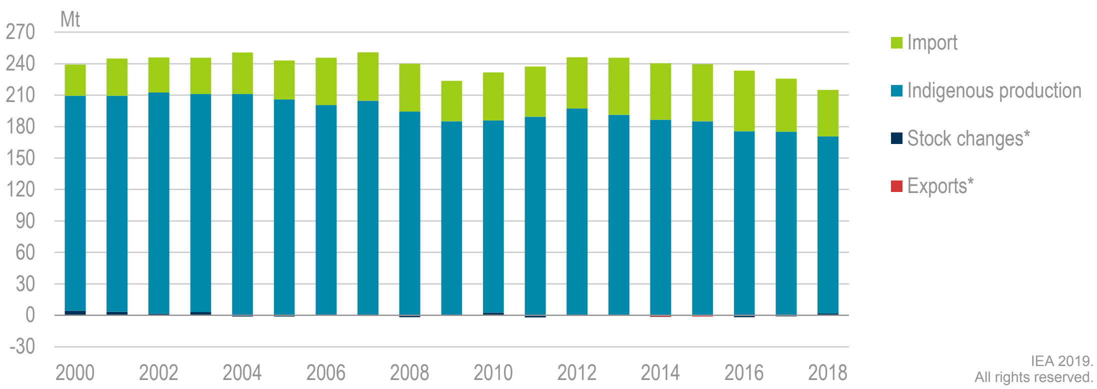
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

This trend will last for the next few years, as Germany plans to phase out coal-fired power plants by 2038. Around 80% of coal is used for power and heat generation and most of it comes from domestic lignite production. While a coal phase-out will lead to significant CO_2 emission reductions, the transition can have a large impact on the electricity system as well as on coal mining regions. Germany should carefully consider the cost allocation of the coal power phase-out as well as look into alternative uses for retiring coal plants and mines to support the energy transition both nationally and regionally.

Supply and demand

Germany's coal supply consists of domestic production of lignite (brown coal) and imports of hard coal (Figure 9.2). In 2018, Germany produced 169 million tonnes (Mt) of coal, 98% of which was lignite and 2% hard coal. Domestic production covered 78% of total coal supply by weight and 55% by energy content. The rest was imported, with the Russian Federation (hereafter "Russia") supplying 43% of total imports, followed by the United States, Colombia and Australia (Figure 9.3). In 2017, the total amount of imported coal was 44 Mt.

Figure 9.2 Coal supply by source, 2000-18

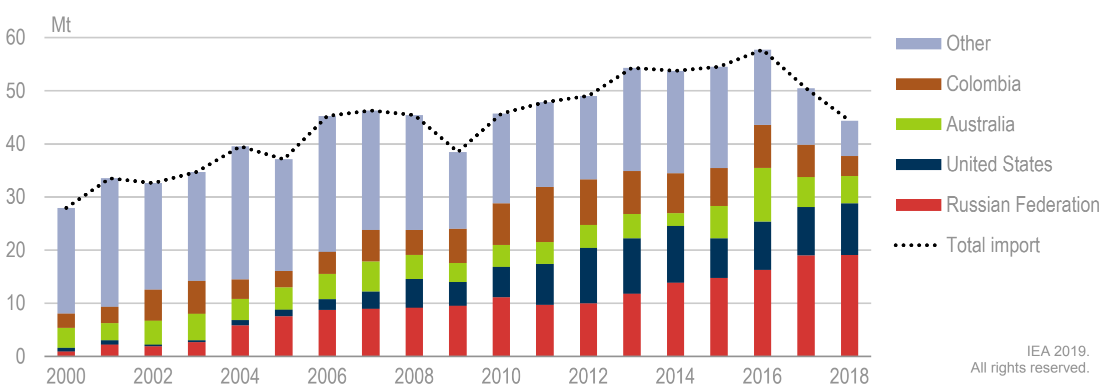


Most coal used in Germany is produced domestically. However, in the last decade, indigenous production dropped by 13% while coal imports decreased by 2%.

*Not clearly visible on this scale.

Source: IEA (2019b), *Coal Information 2019*, www.iea.org/statistics.

Figure 9.3 Hard coal imports by country, 2000-18



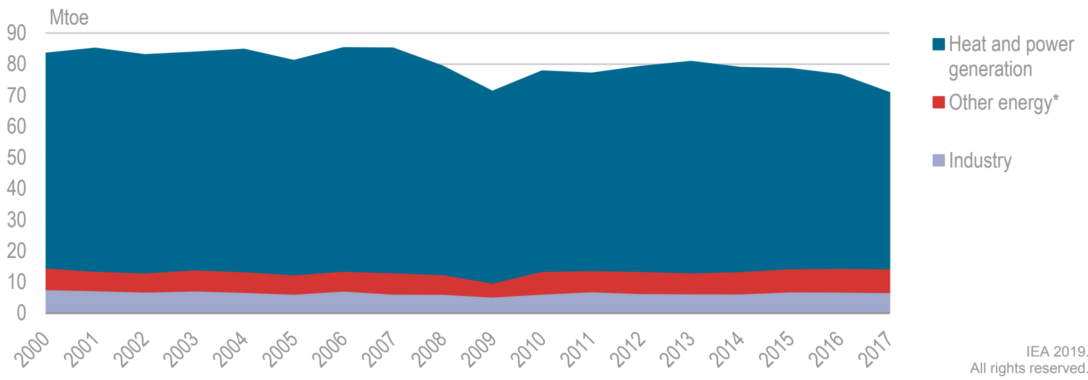
Hard coal production in Germany has been replaced by imports for the last decade, and export capacity was limited to a few European countries nearby.

Source: IEA (2019b), *Coal Information 2019*, www.iea.org/statistics.

Total coal supply decreased by 13% between 2008 and 2018, mainly due to a drop in hard coal production. Over the past decade, domestic hard coal has been largely replaced by imports, while lignite production has remained more stable at an average of 175 Mt over the same period.

Most of Germany's coal consumption is used in heat and power generation. In 2017, the sector accounted for 79% of total coal consumption (in energy terms), and the rest was used in industry and other energy sectors (Figure 9.4). Coal demand has fallen by 17% in the last decade (from 86 million tonnes of oil equivalent [Mtoe] in 2007 to 71 Mtoe in 2017) due to the reduced use of coal for heat and power generation. Meanwhile, the amount of coal used for industry and other energy has been relatively stable, with a small increase in recent years. Coking coal represented around 16% of total coal usage.

Figure 9.4 Coal consumption by sector, 2000-17



Coal used for heat and power generation accounts for 79% of the total in 2017, but has declined in recent years. Coal consumption in industry and other energy is relatively stable.

**Other energy* includes coke ovens and blast furnaces, and coal used in coal mining.
Note: Minor shares consumed in residential and commercial sectors are not visible on this scale
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics.

Coal mining policy

Coal mining has been a mainstay of the German economy for the last century, and still remains a dominant industry in several German states. In particular, Germany's post-war industrial boom was largely powered by hard coal from North Rhine-Westphalia and the Saarland (Appunn, 2019). Moreover, lignite remains a large industry and significant source of employment in many regions. As such, the government's planned coal phase-out (see below section on coal phase-out) will have important economic and political implications for Germany, especially on a regional basis.

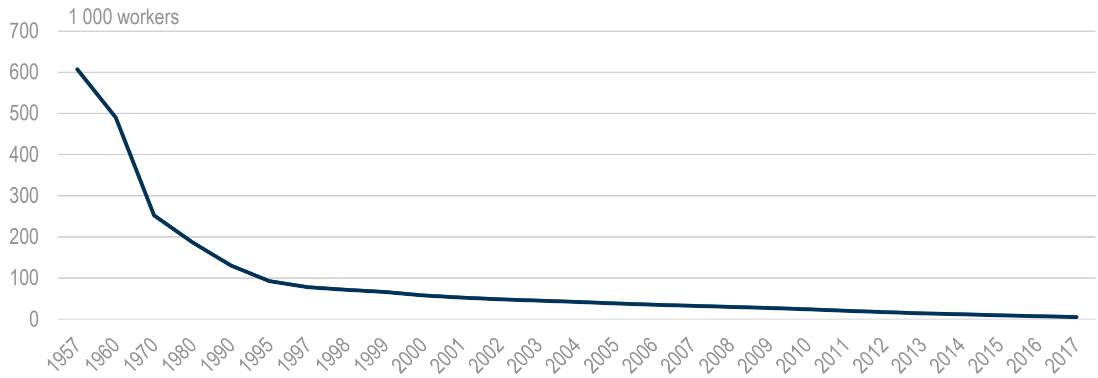
Hard coal

At the end of 2018, Germany ended its production of hard coal, with the closure of the Prosper-Haniel mine in December. For decades, domestic hard coal production struggled to stay competitive against cheaper imports, most recently from Russia, the United States, Australia and Colombia, requiring hefty subsidies from the German government since the 1960s to keep production afloat (The Local.de, 2018). In 2010, the subsidy for hard coal mining cost the government EUR 2 billion; in 2018, it still amounted to EUR 1.1 billion.

In 2007, the German government decided to phase out subsidies for hard coal mining, and close the last hard coal mine by the end of 2018 (though will still provide funds for mine closures). The decision was based on an agreement among the federal government, the coal mining states of North-Rhine/Westphalia and Saarland, industry, and unions. The eleven-year phase-out was designed to provide a sufficient transitional period to coal miners and local economies, thereby ensuring a smoother adjustment. As a result, from 2019 onwards, demand for hard coal will be covered by imports only.

As part of the deal on mine closures, coal miners over 50 years old qualified for immediate pension benefits, while younger workers were retrained for other fields of work. Though hard coal mining employment ceased, work will still be needed at former mine sites to undertake mine clean-up and reclamation efforts.

Figure 9.5 Hard coal mining sector employment in Germany



Source: Reproduced from Statistik der Kohlenwirtschaft e.V., *Overview of Hard Coal 1957-2017* [database], https://kohlenstatistik.de/.

Lignite

In contrast to hard coal, lignite mining remains prevalent in Germany, though is not subsidised by the government. Primarily used in power generation, lignite is mined in open-cast mines in three coal-mining areas: Rhineland (North-Rhine/Westphalia), Central Germany (Saxony-Anhalt/Saxony) and Lausitz (Brandenburg/Saxony). The lignite is used in nearby power stations and district heating facilities. In mining regions, the sector is of substantial economic importance, as power stations and mines together employ about 20 000 people, while the jobs of an additional 40 000 people are indirectly linked to the lignite sector (BMWi, 2019). As these parts of the country are less industrialised, there is little alternative employment.

In recent years, some lignite mining sites have come under pressure from environmental protests, notably over deforestation in the Hambach Forest of North Rhine-Westphalia, where RWE operates its Neurath and Niederaussem mines (Deutsche Welle, 2019). A court injunction against logging in October 2018 was followed in February 2019 by a state moratorium (until autumn 2020) on logging in the forest, cutting the production outlook at the mines (Argus Media, 2019). The government-appointed Coal Commission (see below section on coal phase-out) also recommended keeping the forest intact.

EU emissions limits

In July 2017, the European Union (EU) adopted new limits on emissions from large combustion facilities, including dust, sulphur, nitrous oxides and mercury (known as Best Available Technologies for Large Combustion Plants, or LCP BREF). The threshold values for nitrous oxide were set at no more than 175 milligrammes per cubic metre (mg/m^3) for existing coal plants with capacity of greater than 300 megawatts (MW). The range of emissions for Germany's lignite plants is 160 mg/m^3 to 190 mg/m^3, though most fall above the 175 mg/m^3 level, placing them out of compliance. Hard coal plants of greater than 300 MW are required to meet a threshold of 150 mg/m^3. Mercury levels for existing lignite-fired stations of more than 300 MW are set at <0.001 mg/m^3 to 0.007 mg/m^3, while those for existing coal-fired stations is <0.001 mg/m^3 to 0.004 mg/m^3.

However, the German government rejected the LCP BREF based on the calculation of target levels for nitrous oxide and mercury. Though the European Commission required the new emissions levels to be implemented into national laws and take effect by August 2021, the German government has not issued amendments to the Federal Emission Control Act to implement the rule. Around 600 large combustion plants – mainly hard coal and lignite plants – would be impacted by the changes. German power plants are still expected to comply with the EU regulations and incur the costs of upgrades.

Coal phase-out

As part of its efforts to halve energy-related CO_2 emissions by 2030, Germany intends to phase out coal-based power. To reach a broad social consensus on the coal phase-out plan, the federal government established a Commission on Growth, Structural Change and Employment (also known as the Coal Commission) in June 2018. It brought together representatives of environmental associations, scientists, trade unions, economic and energy associations, and representatives from the affected regions.

The commission presented its report to the government in late January 2019, with a recommendation to completely phase out the 40 gigawatts (GW) of coal power capacity by 2038. If conditions allow, the phase-out could be brought forward to 2035, a decision to be made by 2032. As sub-targets, the commission recommended decommissioning 12.5 GW of coal-fired power plants by 2022 and another 13.1 GW by 2030 (BMWi, 2019).

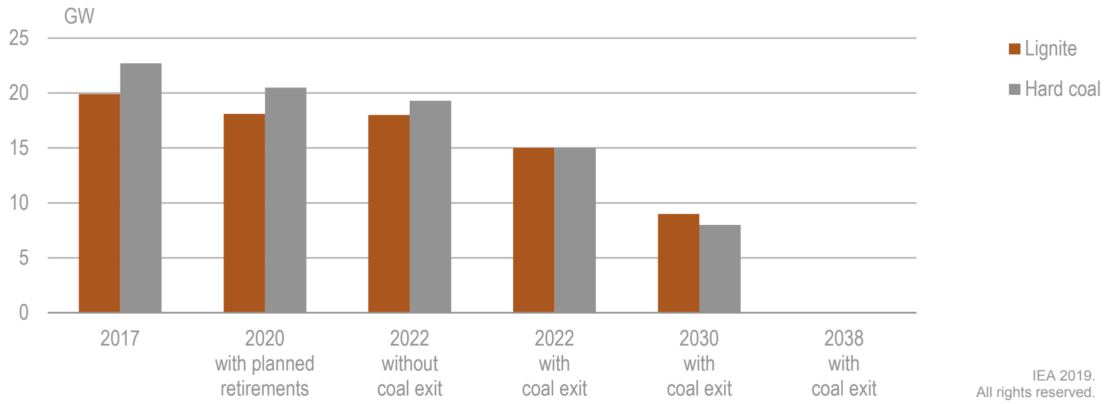
The commission estimates that coal-fired capacity will fall by 3.2 GW from 2017 to 2020, due to retirements or shifting of plants to the capacity reserve (see below on lignite reserve). It expects that after 2020, retirements will continue, but additional closures would be required to meet 2030 and 2050 climate targets (BMWi, 2019).

The report advised against allowing any new coal-fired generation from coming on line, including plants that have already been built but not entered into service. Moreover, it also called for the similar retirement of coal-based heating plants; it proposed incentivising co-generation[13] from cleaner sources in the country's Combined Heat and Power law.

The commission recommended evaluating progress on the plan and the targets periodically, in 2023, 2026 and 2029. In particular, it advised reviewing the 2038 end date for coal usage in 2026 and 2029, taking into consideration factors such as power prices, energy security, employment and economic development.

[13] *Co-generation* refers to the combined production of heat and power.

Figure 9.6 Installed coal power capacity before and after the coal exit suggested by the Coal Commission



Source: BMWi (2019), *Commission on Growth, Structural Change and Employment: Final Report*, www.bmwi.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.pdf?__blob=publicationFile&v=3.

Furthermore, the commission proposed that coal mining regions, coal miners, electricity customers and coal plant owners receive EUR 40 billion over 20 years in transitional assistance. Notably, the report recommended funding the transitional assistance through the federal budget rather than a surcharge on electricity. The commission also addressed the issue of power prices, which it expects will go up with the coal exit. As such, it recommended creating a compensation mechanism for power consumers, especially energy-intensive industries, paid from the federal budget (as part of the EUR 40 billion assistance package).

The coal phase-out would have important implications for Germany's energy security, especially in a context where the country is also phasing out nuclear power by the end of 2022. Though Germany has ambitious plans to increase its reliance on variable renewable electricity, it will also become more dependent on natural gas for electricity generation. Gas supply security concerns, including a heavy dependence on imports, will filter through to electricity supply security concerns as well.

To address energy security risks, the commission advised conducting continuous stress tests of the electricity system, in particular the role of new gas-fired generation and storage capacity in meeting load needs, as well as identifying shortfalls in investments that should be addressed through incentives. As part of this effort, the report recommended extending subsidies for new gas-fired co-generation units over 2023-30, in addition to the expected ramp-up in utilisation of existing gas-fired generation capacity and further development of modern flexible co-generation systems.

In order to prevent a collapse in the EU Emissions Trading System's CO_2 price, the commission recommended removing allowances from the market based on the CO_2 savings each time a coal unit shuts down.

The government is in the process of formulating legislation that reflects the proposals of the commission (though it is under no obligation to follow the recommendations), with a target to finalise a plan by early 2020. In May 2019, the government approved EUR 40 billion in transitional economic assistance to affected regions, per the commission's recommendations.

Lignite power reserve

The 2016 Act on the Further Development of the Electricity Market called for two capacity reserves to serve as emergency supply in the event that the market fails to deliver enough electricity. In addition to a 2 GW technology-neutral reserve after 2020, it ordered the creation of a last resort reserve (known as "Sicherheitsbereitschaft") of decommissioned lignite power plants that receive compensation to serve as backup for a period of four years. Eight lignite plants with a collective capacity of 2.7 GW were selected to enter the Sicherheitsbereitschaft reserve at a cost of EUR 1.6 billion (Raus, 2016). Importantly, the reserve can contain only power plants that are not part of the regular power market. The European Commission approved the capacity reserve under state aid rules in February 2018, and it entered into force in February 2019. Plants were taken off the market and directed into the reserve over the period 2016-19. After a plant has been in the reserve for four years, it will be decommissioned.

R&D and technology development

In the current discussions on a coal phase-out, the government does not anticipate offering exemptions for clean coal technologies. Still, the government offers some ongoing research support on power plant efficiency and on CO_2 technologies, including carbon capture, utilisation and storage (CCUS). Germany is member of the international initiative, Accelerating CCS Technologies (ACT), which provides research funding for innovative CCUS projects. ACT launched its second call for project proposals in June 2018, for up to EUR 30 million (ACT, 2019). Moreover, a special working group for CO_2 technologies was established as part of the German research network for Flexible Energy Conversion, which will include research on CO_2 capture and utilisation (Kraftwerkforschung, 2019).

Germany is also considering options to convert older power plants into large, centralised storage sites to facilitate the expansion of renewable power. The existing grid connections of these plants would be considered an asset in this regard. Moreover, the conversion of these power plants would also be a source of economic activity in coal regions. The German Aerospace Center (DLR) is currently working on a pilot project with the German utility Vattenfall and start-up SaltX to replace the old boiler at the Reuter coal power plant in Berlin with a molten salt thermal storage tank that will be heated using excess renewable energy (Buchsbaum, 2019; Deign, 2019).

The Coal Commission also recommended the option to convert coal-fired power station sites in the coal mining region of Lausitz – expected to be hit the hardest by the coal phase-out – into modern industrial parks sourced by renewable energy.

Assessment

Coal is Germany's third-largest energy source in TPES, and with 38%, is still the largest source for electricity generation. Germany's coal demand fell rapidly in the early 1990s, but has since been relatively stable at around 80 Mtoe per year, with a slight decline in the last few years. In 2017, total consumption was 71 Mtoe; power and heat generation accounted for 79% of this.

Most of Germany's coal supply comes from domestic brown coal (lignite) production. In 2018, Germany produced 35.7 Mtoe (166 Mt) brown coal and 1.9 Mtoe (3 Mt) hard coal. Lignite is mostly used for heat and power generation; hard coal is also consumed in the industry sector. Domestic production covered 56% of total coal supply in energy terms in 2017 (79% in weight), but imports (of hard coal) have increased slightly in the last decade. Of hard coal imports in 2018, 43% were from Russia, 22% from the United States, 12% from Australia and 9% from Colombia.

At the end of 2018, Germany ended its production of hard coal, based on an agreement among the federal government, the coal mining states of North-Rhine/Westphalia and Saarland, industry, and unions. This also ended the subsidy for coal mining, which stood at EUR 2 billion in 2010, and declined to EUR 1.1 billion in 2018. From 2019 onwards, demand for hard coal will be covered by imports only.

Lignite, primarily used in power generation, is mined in open-cast mines in three coal-mining areas: Rhineland (North-Rhine/Westphalia), Central Germany (Saxony-Anhalt/Saxony) and Lausitz (Brandenburg/Saxony). Lignite mining is not subsidised by the government. The lignite is used in nearby power stations and district heating facilities. In mining regions, the sector is of substantial economic importance, as power stations and mines together employ about 20 000 people, while the jobs of an additional 40 000 people are indirectly linked to the lignite sector (BMWi, 2019). As these parts of the country are less industrialised, there is little alternative employment.

As part of its efforts to halve energy-related CO_2 emissions by 2030, Germany intends to phase out coal-based power altogether. To reach a broad social consensus on the coal phase-out plan, the federal government established a Commission on Growth, Structural Change and Employment (Coal Commission) in June 2018. It brought together representatives of environmental associations, scientists, trade unions, economic and energy associations, and representatives from the affected regions. The commission presented its report in January 2019, with a recommendation to close all 40 GW of coal power capacity by 2038 at the latest. If conditions allow, the phase-out could be brought forward to 2035, an option to be assessed by 2032. As sub-targets, the commission recommended decommissioning 12.5 GW of old and inefficient coal-fired power plants by 2022 and another 13 GW by 2030. Progress on the plan would be periodically evaluated in 2023, 2026 and 2029. Furthermore, the commission proposed that coal mining regions should receive EUR 40 billion in transitional assistance (coming from the federal budget), spread out over 20 years, as not only the coal-fired power plants will close, but also the lignite mines.

The government is in the process of legislating a coal phase-out based on the proposals of the commission. In the current discussion on a coal phase-out, exemptions for clean coal technologies are not anticipated. Nevertheless, there is ongoing research on power plant efficiency and on CO_2 technologies, including CCUS.

The International Energy Agency (IEA) recognises the envisaged coal phase-out as an effective tool to achieve more significant greenhouse gas emissions reductions in the country. The IEA acknowledges that a phased approach is necessary as coal is still the largest source of electricity generation and, together with nuclear power (to be phased out completely by 2022), accounts for 50% of generation. Therefore, time is needed to learn to operate such a large system as Germany's with much higher shares of variable renewable generation, and to provide the right market signals for investments in the future generation mix of dispatchable and variable sources.

The phase-out will have large economic and social implications for some regions, which needs to be addressed as well. As the government decides on the recommendations of the Coal Commission, it should look at whether the large assets of the power plants that need to close can have a second useful life in supporting the energy transition, for instance by turning these facilities into large thermal storage sites that can support lower temperature district heating systems directly or electricity generation indirectly.

As coal is mostly used in power generation, the government might be tempted to finance the programmes to support the regions with a surcharge on electricity consumption, similar to the Renewable Energy Act (EEG) surcharge for renewables support. The IEA would caution not to burden the electricity price any further, as expensive electricity already hinders sector coupling, i.e. use of electricity in heat and transport to reduce the use of fossil fuels in those sectors.

Recommendations

The government of Germany should:

- ☐ Allocate the costs of the coal phase-out in a way that does not increase the price differentials of energy use between different sectors (electricity, heat and transport), so as to not hamper sector coupling.
- ☐ Investigate options for repurposing retiring coal plants and mines to provide zero-emissions sources of system services, for example thermal storage, to support the energy transition.

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10. Oil

Key data

(2018 provisional)

Domestic oil production: 71.1 kb/d, -27% since 2008

Net imports of crude oil: 1 719.8 kb/d, -19% since 2008

Domestic oil products production: 2 064 kb/d

Net imports of oil products: 384.2 kb/d, +69% since 2008

Share of oil: 32.8% of TPES and 0.8% of electricity generation

Consumption by sector (2017): 103.0 Mtoe* (transport 52.4%, industry 21.6%, residential 11.0%, commercial 6.9%, other energy 6.7%, heat and power generation 1.3%)

*Demand data are presented in energy units (Mtoe) for comparisons over different fuels and sectors.

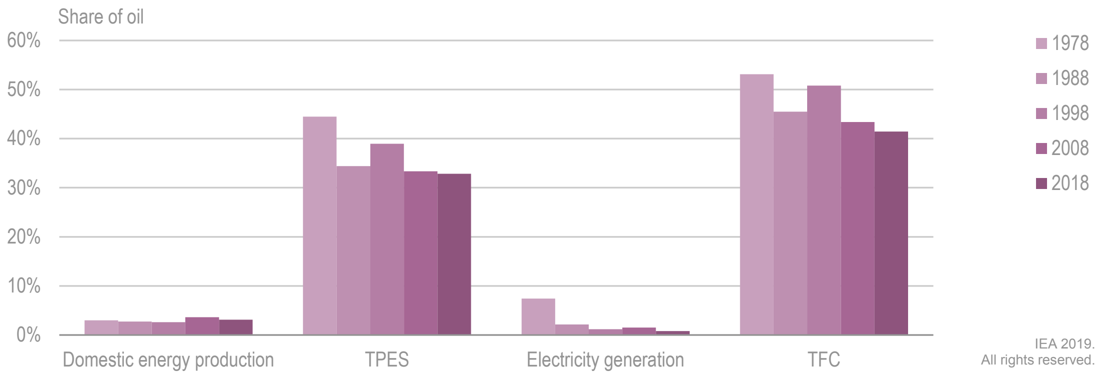
Overview

Despite the country's limited oil resources and stagnant domestic production, oil is still the most dominant energy source in Germany, accounting for 33% of total energy supply (TPES) in 2018. Germany's demand for oil decreased slightly over the last decade but at a much slower rate than that of domestic oil production, continuing its heavy reliance on oil imports. Transport is the largest oil-consuming sector, accounting for more than half of total oil consumption; diesel is the primary oil product consumed, followed by gasoline and other gasoil used mainly for heating.

Germany has diversified oil supply sources, a well-connected supply infrastructure and a liberal market that contributes to maintaining the country's strong security of oil supply. More progress on fiscal incentives, such as tax differentials and subsidies for low-emissions vehicles and associated infrastructure, can further support Germany's oil security as well as the low-carbon transition by reducing demand for oil in the transportation sector.

Germany has consistently met the International Energy Agency's (IEA's) 90-day oil stockholding obligation, and its oil stock level is well above the minimum requirement. As of the end of May 2019, Germany held 122 days of net imports, equivalent to 240 million barrels (mb) (31 million tonnes of crude oil equivalent [Mtoe]).

Figure 10.1 Share of oil in different energy metrics, 1978-2018



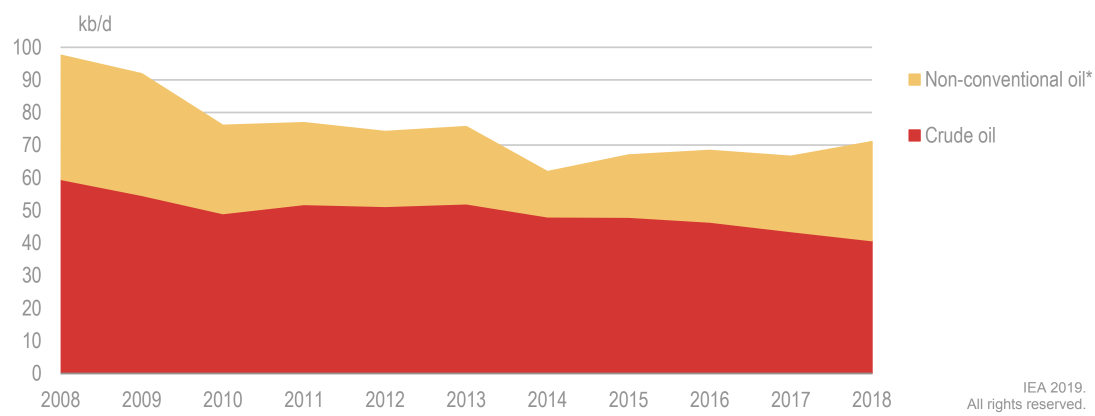
Oil is the largest energy source in Germany with over 30% of TPES and 40% of TFC; the share of oil in the energy supply has remained stable in the last decade.

Notes: 2018 data are provisional. Latest data for TFC are for 2017.
Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

Supply and demand

In 2018, Germany's domestic oil production was 71.1 kb/d (Figure 10.2). Over the last decade, Germany's total oil production has declined by 27% mostly due to declines in both crude and non-conventional oil between 2008 and 2014. Since 2014, non-conventional oil production (biofuels as refinery additives) have started to pick up and more than doubled to 30.4 kb/d.

Figure 10.2 Domestic oil production, 2008-18

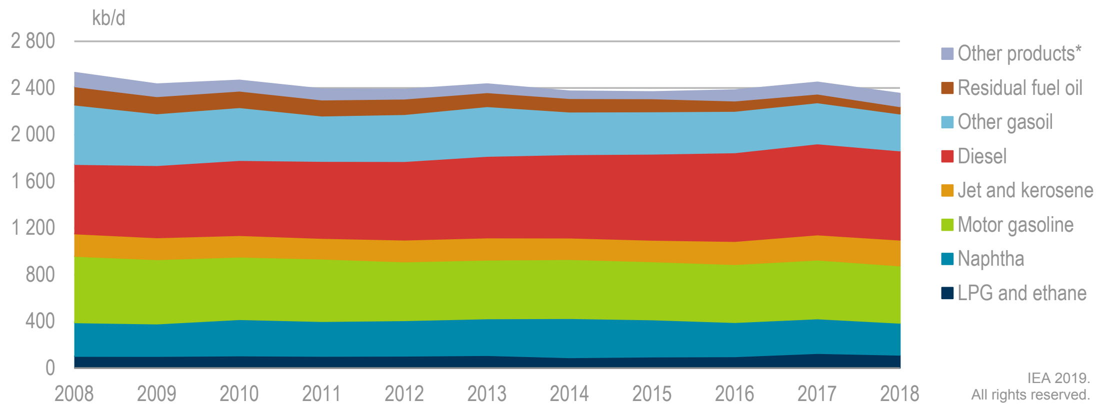


Germany's oil production has picked up since 2014 due to an increase in non-conventional oil, mostly biofuels additives, while crude oil production continues to fall.

*This category includes synthetic crude oil from tar sands, oil shale, etc.; liquids from coal liquefaction; liquids from gas-to-liquids processes; hydrogen and emulsified oils; refinery additives; and methyl tert-butyl ether (MTBE).
Note: No natural gas liquids (NGLs).
Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Germany has limited domestic oil production concentrated in the states of Schleswig-Holstein and Lower Saxony. The only offshore production of crude oil comes from Mittelplate, located about seven kilometres off the Schleswig-Holstein North Sea coast (BMWi, 2019). Production from the two largest oil fields in Germany – Mittelplate and Dieksand – has dropped quite sharply since 2016 as the country's total oil reserves continue to fall.

Figure 10.3 Oil demand by product, 2008-18



Germany's total oil demand has been stable over the last decade with increasing diesel demand for transport.

**Other products* include crude oil, "other" NGLs, synthetic fuels, Orimulsion, hydrogen, synthetic crude, refinery gas, aviation gasoline, naphtha-type jet fuel, white spirit, industrial spirit (specific boiling point [SBP]), lubricants, bitumen, paraffin waxes, petroleum coke, tar, sulphur, aromatics and olefins.

Note: LPG = liquefied petroleum gas.

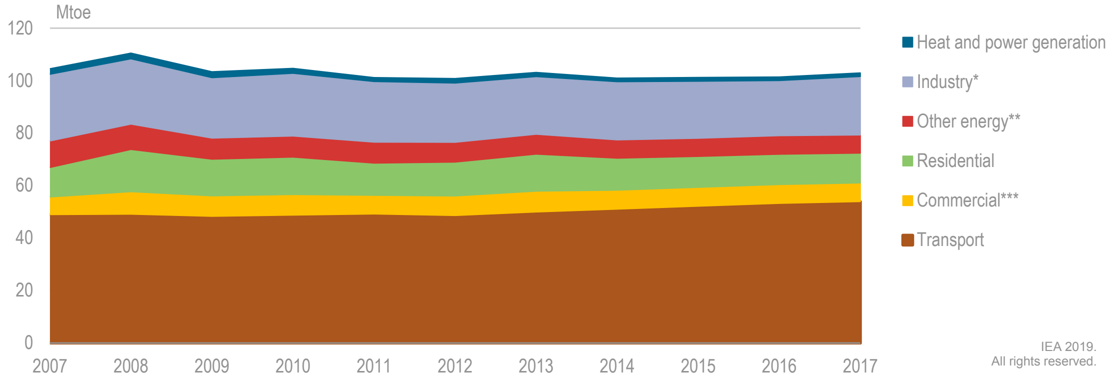
Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Oil demand has been stable in the last decade, after a 21% decline in the previous decade from 1997 to 2007. In 2018, Germany's total oil demand was around 2 354 kb/d (Figure 10.3). Fuels for transport – diesel and gasoline – were the most heavily consumed oil products, with diesel accounting for 32% of total demand and gasoline for 21%. By absolute volume, demand for diesel showed the largest increase of 28% over the last decade, while that for gasoline declined by 14%.

Other gasoil and residual fuel oil, used mostly for residential and commercial heating, accounted for 20% (other gasoil) and 3% (residual fuel oil) in 2018. While other gasoil remained the third-largest oil product, its demand has declined significantly by 38% over the last decade; residual fuel oil demand marked the sharpest decrease of 60%. Naphtha, LPG and ethane are still minor oil products used as feedstocks for industry in Germany. In the last ten years, demand for naphtha fell slightly by 5% but LPG and ethane demand grew by 10%, with LPG accounting for 12% and ethane for 5% of total oil products demand in 2018.

In line with the oil products demand trend, the transport sector remained the largest oil consumer with over half of total oil consumption in Germany. Only the transport sector showed an increase in the share of total oil consumption from 47% to 52% in 2007-17 with small declines from all other sectors (Figure 10.4). The second-largest oil consumer was the industry sector, mostly chemicals and petrochemicals, which accounted for 22% of the total in 2018, followed by residential (11%), commercial and other energy (7% each), and heat and power generation (1%).

Figure 10.4 Oil demand by sector, 2007-17



The transport sector remains the largest oil-consuming sector in Germany.

**Industry* includes non-energy consumption.

***Other energy* includes consumption in refineries.

****Commercial* includes commercial and public services, agriculture, forestry, and fishing.

Note: International bunkering is not part of TPES.

Source: IEA (2019a), *World Energy Balances 2019,* www.iea.org/statistics/.

With renewable energy becoming more competitive, oil consumption in heat and power generation more than halved over the last decade to just under 1% of total oil consumption in 2018.

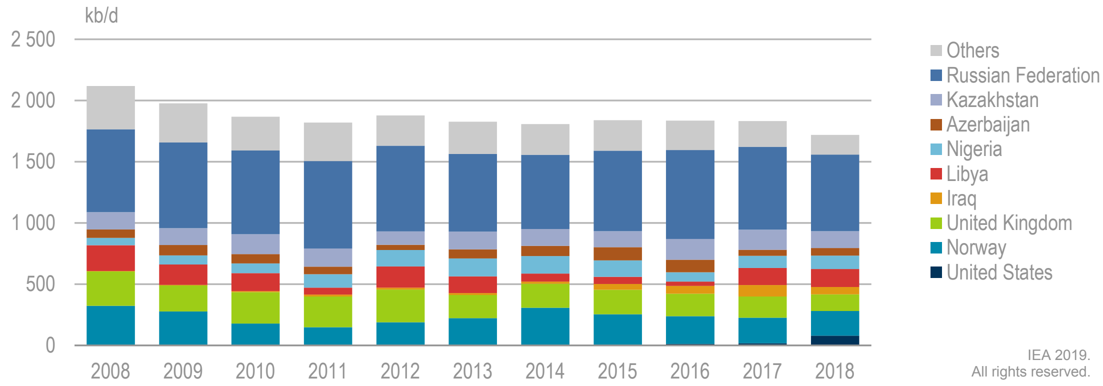
Trade

Germany has a high level of oil import dependency[14] at around 97%. In 2018, Germany's total oil net imports were 2 104 kb/d (imports: 2 561 kb/d; exports: 457 kb/d), of which crude oil net imports accounted for 82%.

Since 2008, Germany's crude oil net imports declined by 19% to 1 719.8 kb/d in 2018 (Figure 10.5), though a major refinery outage and low water levels in the Rhine River that prompted reduced refinery throughput contributed to atypically lower crude imports in 2018. The Russian Federation (hereafter "Russia") remained Germany's dominant crude oil supplier and provided 36% of total imports. European neighbours such as Norway delivered 12% of the total and the United Kingdom 8%, but their shares have been falling over the last decade. Increasingly, more crude oil came from Organization of the Petroleum Exporting Countries OPEC countries such as Libya (8%), Nigeria (6%) and Iraq (4%). The United States has been exporting crude oil to Germany since 2015 and delivered 79 kb/d in 2018, equivalent to 5% of total crude oil imports. Crude oil from Kazakhstan and Azerbaijan remained stable over the last decade; Kazakhstan accounted for 8% of total imports in 2018 and Azerbaijan for 4%. Germany does not export any crude oil.

[14] Oil import dependency calculated as domestic oil production divided by total oil demand.

Figure 10.5 Crude oil net imports by country, 2008-18



Germany has not only reduced the level of crude oil imports but also diversified import sources over the last decade.

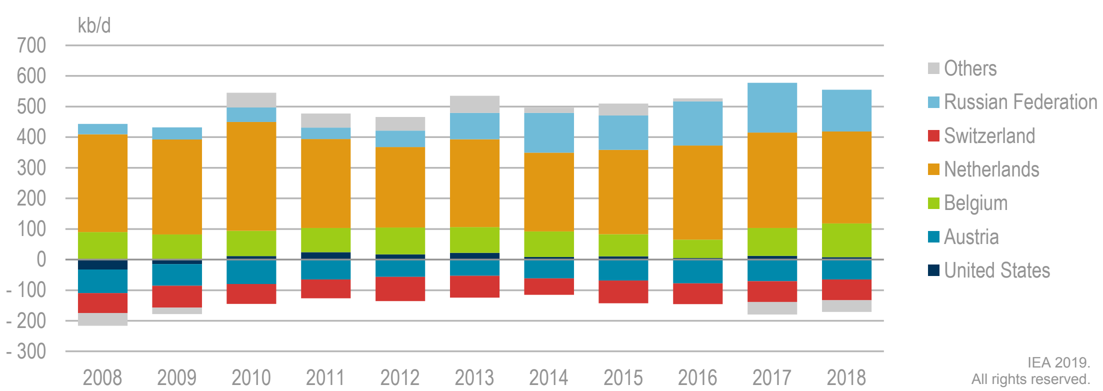
Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

In terms of oil products, Germany produces most of its demand in domestic refineries. In 2018, it produced 2 064 kb/d of oil products, which covered 88% of total demand. However, Germany's net imports of oil products have increased by 69% over the last decade to reach 384.2 kb/d in 2018 (Figure 10.6).

Of total imports (841.1 kb/d) in 2018, oil products mostly came from the Netherlands (48%), Belgium (18%) and Russia (16%). Imports from Russia increased by almost four times to 138.3 kb/d in 2018. Although still minor, the United States became a net exporter of oil products to Germany in 2010.

Germany's oil products exports were 456.9 kb/d in 2018, which were delivered almost entirely to neighbouring European countries. The Netherlands accounted for the largest share at 22%, followed by Austria and Switzerland (16% each), and Belgium and Poland (10% each). Among those trading countries, Austria, Switzerland and Poland are net importers of Germany's refined oil products.

Figure 10.6 Oil products net imports by country, 2008-18



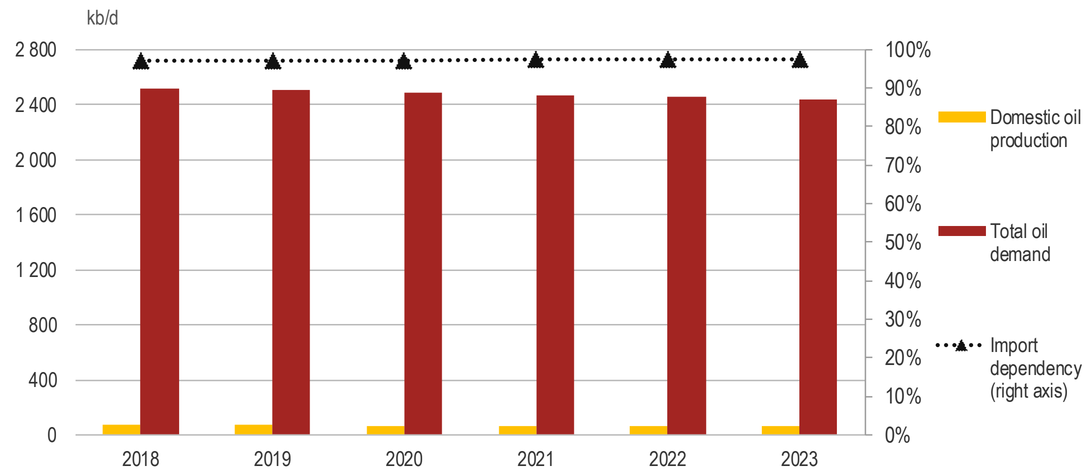
Germany's net imports of oil products increased by almost 70% over the last decade.

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Germany's oil supply and demand outlook

Germany is highly dependent on oil imports. In 2018, Germany's domestic oil production accounted for only 4% of total oil supply. Over the next five years, Germany's total oil demand is expected to decline by 3% while domestic oil production is projected to fall four times faster at 12%. As a result, the country's oil import dependency will further increase, albeit by a small margin, and stay at around 97% over the next five years (Figure 10.7).

Figure 10.7 Germany's oil supply and demand outlook, 2018-23



Germany's oil import dependency is expected to further increase and stay at around 97% in the next five years

Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

A steady fall in the sales of mineral oil products, refinery accidents (such as an explosion in the Vohburg refinery in September 2018 that caused an abrupt production loss), and increasing supply bottlenecks due to low water levels in the Rhine and higher transport costs are all contributing to the recent downturn in Germany's oil industry. Falling global oil prices have also discouraged investments. On the other hand, a sustained level of employment for refinery overhauls (turnarounds) and modernisation (efficiency increases, emission reductions, product range adjustments and logistics) are expected to lend a small boost to the German oil industry.

Oil industry structure

The German oil market has been liberalised and competition-driven for many years with numerous companies in the downstream and retail sectors that are independent from both the public and large multinational companies.

Upstream

Under the Federal Mining Act 1980, the German state (*Länder*) authorities are in charge of approving exploration and production (E&P) activities as well as imposing levies on them. Although there are no specific restrictions on oil production in Germany, they can arise from environmental laws, particularly water and nature preservation laws. An environmental impact assessment is also required for commercial oil production if the extracted amount exceeds 500 tonnes of oil per day.

The standard mining royalties are set at 10% of the average attainable market value. For some *Länder*, extraction levies are still an important source of revenue; in 2017, E&P companies paid a total of EUR 250 million as royalties.

The companies involved in the production of oil and natural gas are organised in the economic association Erdöl- und Erdgasgewinnung e.V. (BMWi, 2019). Currently, only a few companies are active in Germany's oil E&P sector. There has been little change to the major players over the last five years with Wintershall Holding GmbH, DEA Deutsche Erdoel AG, Engie E&P Deutschland GmbH, and BEB Erdgas und Erdöl GmbH & Co. KG still being the most dominant ones.

Downstream

Compared with the upstream sector, Germany's refining sector is more dynamic, with various global oil companies holding German refining capacity. The public sector does not own any shares in refineries, and there is no specific government regulation for the refining sector, other than applicable environmental regulations.

At the end of 2017, Germany had 13 refineries with a total annual processing capacity of 103 million tonnes (Mt) (see refinery section below for details). Shell Deutschland Oil is the largest refining operator with a 25% share of total refining capacity, followed by BP Europa SE (18%), Rosneft Deutschland GmbH (12%), Total SA (11.7%) and Holborn Investment Company (5%); the remaining eight companies hold shares lower than 5%.

There have been some ownership changes in recent years. In 2014, the Elbe Mineralolwerke Refinery Center in Hamburg-Harburg (2.85 Mt) closed down. In addition, Rosneft and BP ended their joint venture in the Ruhr Oel refinery on 1 January 2017, leaving BP as its sole owner. In early 2016, the Swedish company Nynas AB took over Shell's refinery in Hamburg-Harburg, and has since controlled 2.1% of Germany's total refining capacity. The administration does not expect the consolidation within the refining sector to affect Germany's security of supply.

Retail

In the retail fuel sector, there were around 14 093 roadside filling stations and 360 filling stations on the autobahns as of July 2019. The number of filling stations has decreased slightly from 14 209 stations in 2014. The major players in Germany's oil retail sector are Shell, with a market share of 21%, and Aral, with 20%, followed by JET (Phillips66) (10.5%), Total (9.5%) and Esso (7.0%).

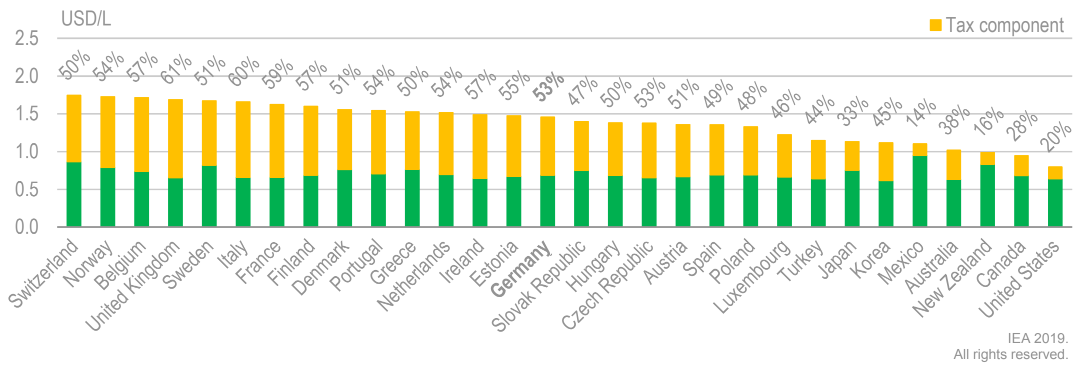
In 2011, the Federal Antitrust Authority (Bundeskartellamt) reviewed and confirmed an oligopolistic market structure consisting of the five largest retailers in Germany's fuel retail sector, resulting in a uniform process at service stations. To prevent further concentration of the market, the federal government created a special unit to monitor and publicise fuel price information to consumers in 2013 (see oil market and policies section below).

Prices and taxation

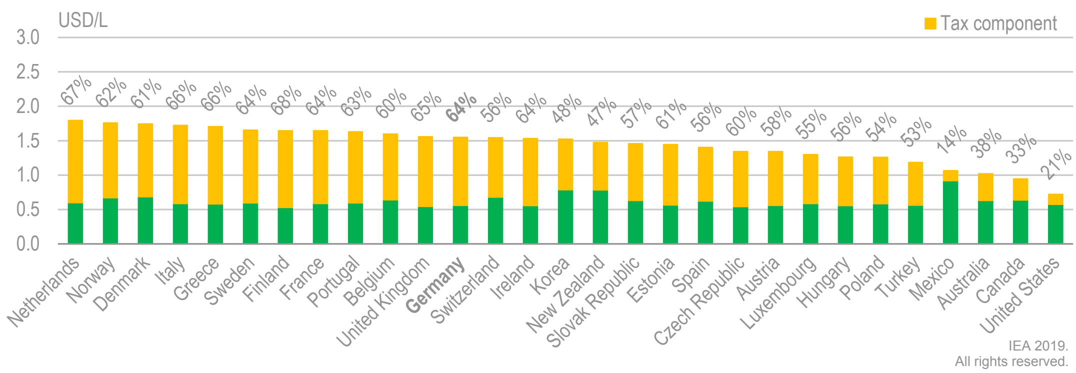
There is no fuel price regulation in Germany aside from the competition oversight of the Bundeskartellamt. Fuel prices in Germany are close to the median among IEA member countries for diesel and gasoline, but among the lowest for fuel oil, mainly due to low tax rates (Figure 10.8).

Figure 10.8 Oil fuel prices in IEA member countries, Q1 2019

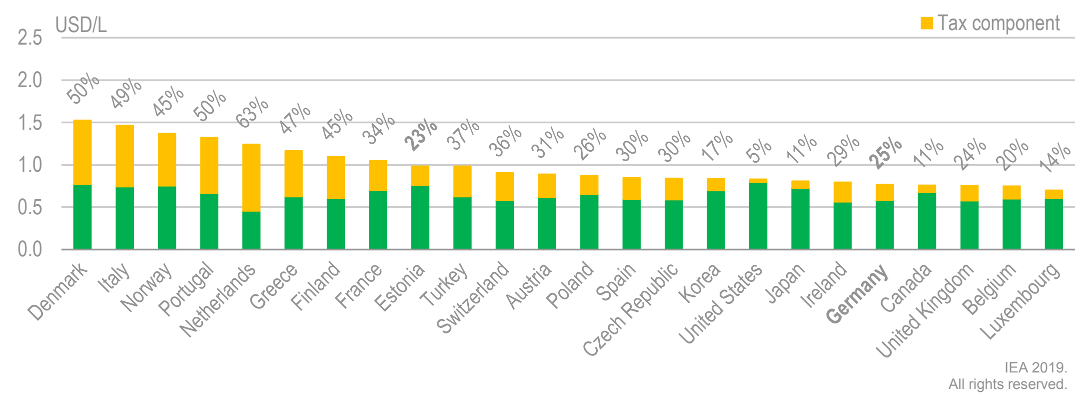
Automotive diesel fuel



Premium unleaded gasoline (95 RON)



Light fuel oil



Fuel prices in Germany are close to the median among IEA member countries for diesel and gasoline, but the third-lowest for fuel oil mainly due to low tax rates.

Notes: L = litre. Premium unleaded gasoline data are not available for Japan, or for light fuel oil in Australia, Hungary, Mexico, New Zealand, the Slovak Republic and Sweden.

Source: IEA (2019c), *Energy Prices and Taxes First Quarter 2019*, www.iea.org/statistics/.

The federal government in 2013 created a Market Transparency Unit for Fuels (MTU Fuels) under the Bundeskartellamt. By collecting and providing fuel price information to consumers, the MTU enhanced the transparency of fuel prices as well as market competition.

Taxation

Along with other fossil fuels, oil is subject to energy taxation in Germany. The Energy Tax Act 2006 and the Energy Tax Implementation Ordinance 2006 in their current forms are the legal basis for domestic taxes; at the European Union (EU) level, energy taxation is guided by Council Directive 2003/96/EC. The energy tax is limited to energy products used as vehicle or heating fuels; non-energy related uses such as chemical feedstocks are exempt. To account for broad environmental and economic considerations, the Energy Tax Act allows for tax concessions, which are applied to fuels used in agriculture and forestry, local public transport, aviation, shipping, and manufacturing. For 2018, the government estimates that the total amount of fuel tax concessions was around EUR 4.4 billion.

Transport fuels

As in other European countries, oil products for transport are heavily taxed. In 2018, unleaded gasoline had a tax rate of EUR 65.45 cents per litre (c/L), and diesel EUR 47.04 c/L. Such a tax differential between gasoline and diesel is relatively high in the European context at present; many countries have narrowed the differential rate between the two fuels to account for local diesel-related air pollution (some European countries now even tax diesel at a higher rate than gasoline). LPG and natural gas used as motor fuels benefit from lower tax rates, which are scheduled to be phased out by 2022 for LPG and 2026 for natural gas.

There is tax relief of EUR 5.4/L for local public transport, covering rail and road, applied evenly for both gasoline and diesel. The total amount of subsidies for local public transport is estimated to be EUR 72 million. Fuels used for aviation and shipping (on internal waterways) are exempt from taxation if they are for commercial provisions of services.

The German government also provides subsidies for the purchase of low-emission vehicles as well as the deployment of electric vehicle (EV) charging infrastructure and hydrogen filling stations (see section on oil in the low-carbon transition below).

Heating fuels

A special tax rate is applied for residential heating fuels in Germany. In 2018, the tax rate for heating oil was EUR 6.135 c/L, and for heavy fuel oil only EUR 2.5 c/L, allowing for very low heating fuel prices. As such, current levels of taxation do not support a transition towards low-carbon fuels, especially renewables, in the heating sector.

Oil market and policies

Germany takes a market-driven approach to its oil market and oil pricing, with the regulatory framework mainly centred on preventing anti-competitive behaviour. Currently, there is no intention to introduce additional market regulation beyond the competition oversight of the Bundeskartellamt.

Existing regulations in the German oil market mainly address environmental and safety issues, which are largely derived from EU directives. In order to accelerate the low-carbon transition in sectors such as transport and buildings that still rely heavily on fossil fuels, Germany has introduced new policies and other fiscal measures in recent years that are designed to lower demand for oil, including through efficiency and increased use of alternative fuels.

Oil in the low-carbon transition

The German government is striving to promote low-carbon transitions beyond the power sector to other energy-intensive sectors, particularly transport. Given its heavy historical focus on dieselisation, Germany has been relatively slow in adopting EVs. However, with Germany's major automobile makers shifting their production lines towards electric models, as well as the government's support for low-carbon vehicles, the EV market in the country has expanded rapidly in recent years.

Electric vehicles

To foster the use of EVs, the German government has implemented supporting fiscal measures. Specifically, the government grants a ten-year tax exemption for all-electric vehicles, staring with vehicles registered from 18 May 2011 through the end of 2020. In addition, for light-duty passenger cars, the environmental bonus scheme provides grants worth EUR 4 000 for non-hybrid electric cars and EUR 3 000 for plug-in hybrids (PHEVs) that cost up to EUR 60 000. The automotive industry and the federal government each cover half of the grant.

The government also provides EUR 300 million in funding towards building out EV charging infrastructure. Of this amount, EUR 200 million is granted for rapid charging infrastructure and EUR 100 million for standard charging points. Moreover, it has an aspirational target for at least 20% of new cars procured for the federal government's vehicle fleet to be electric. From January 2019, the government began offering tax relief for company EVs purchased or leased between 1 January 2019 and 31 December 2021.

The federal government also provides a total of EUR 10 million to promote alternative fuels – notably compressed natural gas (CNG), liquefied natural gas (LNG) and hydrogen – in heavy-duty vehicles, which are heavily dependent on diesel.

On the research and development side, German industry is working on developing new types of low-emission fuels such as e-fuels and synthetic fuels. For instance, hydrogen produced using renewable power can be combined with carbon dioxide to generate a hydrocarbon fuel that can be used in conventional cars and emit net-zero greenhouse gases (GHGs). Such synthetic fuels are distinctive in that they can be adopted by conventional cars, including heavy-duty ones, without a need to deploy special infrastructure such as EV charging stations.

As of the end of 2018, there were a total of 177 070 EVs (including battery-electric vehicles and PHEVs) on German roads. The market share of electric cars (by sales) has increased from 0.1% in 2012 to 2.0% in 2018, which is slightly lower than that in France and the United Kingdom (around 2.1%) but significantly lower than that in Norway (46%) or Sweden (8%) (IEA, 2019c).

In addition to increased subsidies for EVs, to further support lowering oil demand in the transport sector, the government's climate cabinet recommended a carbon price on transport fuels, starting at EUR 10/tonne in 2021 and increasing by EUR 5 annually to EUR 35 in 2025. From 2026, the carbon price would transition to an emissions trading system without a fixed price.

Biofuels

Germany also encourages the consumption of biofuels as a way to displace oil in the transport sector. The government's objectives are directed by EU policy as defined under the Renewable Energy Directive, which requires all member states to meet a target of 10% in the transport sector by 2020. In addition, the EU Fuel Quality Directive requires member states to cut GHG emissions from fuels by at least 6% by 2020, which also motivates the increased use of biofuels.

On the domestic front, the German government established biofuels quotas as part of the Federal Immission Control Act (BImSchG) in 2009. The act required oil companies in 2015-16 to reduce GHG emissions by 3.5% relative to the total amount of fuel they supplied to the market, mainly through increased used of biofuels or electricity. In 2017-19, they are required to reduce emissions by 4%, and from 2020, by 6% (BMWi, 2019). In order to credit biofuels under this policy, each category of biofuels must be assigned a GHG reduction value as well as a sustainability certificate.

Furthermore, the government implemented a Biofuel Sustainability Regulation (Biokraft-NachV) to ensure the environmental soundness of biofuels production. The regulation classifies biofuels as sustainable if they achieve a 50% reduction in GHGs compared with fossil fuels (since October 2015). Production of sustainable biofuels must also avoid areas of high biodiversity or rich carbon sinks. Meanwhile, EU regulations since 2017 require that biofuels production avoid indirect land-use changes, limiting the role of conventional biofuels from crops to 7% of the European Union's 10% target. The remaining 3% is supposed to be met with cellulosic and other advanced biofuels, as well as electricity.

Public transport

The German government is also keen to promote the uptake of intermodal transport systems through additional funding, including in collaboration with private-sector infrastructure. Germany's historical competitive edge in automobiles has not motivated sizeable investments and consumer uptake of public transportation. Even long-distance rail is often more expensive and less convenient compared with driving for the average person. To help address this gap, in 2018, the government published a new funding guideline for EUR 500 million until 2023 to promote energy efficiency measures in the rail transport sector. The climate cabinet's 2030 action plan also calls for greater incentives to promote public transportation and the use of trains over airplanes.

Heating

The use of heating oil in buildings has decreased significantly over the past decade thanks to various initiatives, ranging from stricter building codes to the promotion of renewable energies via the Market Incentive Programme (see Chapter 3 on climate change). In newly built buildings, the share of oil heating systems has decreased from over 10% in 2004 to only 0.7% in 2016. Germany expects to further reduce the use of heating oil in the entire buildings sector through existing measures. Moreover, the climate cabinet recommended that the government impose a ban on oil-based heating in buildings from 2026.

Oil supply infrastructure

Notwithstanding its heavy reliance on oil imports, Germany has robust and diversified crude oil infrastructure that allows it to import oil from ports in the North Sea and Baltic Sea, as well as on river barges and pipelines (Eckert, 2019).

Ports

The German crude oil supply system relies on three North Sea ports – Wilhelmshaven, Brunsbüttel and Hamburg – as well as the ports of Rostock and Gdansk/Poland on the Baltic Sea (Figure 10.9). The ports are connected to inland refineries by pipelines. The most important oil port for Germany is Wilhelmshaven, which accounts for approximately a fifth of total crude imports.

Germany also has four cargo ports with infrastructure for product imports. Bremen is used solely for product imports with several firms owning anchoring berths near it. In addition to crude oil, Brunsbüttel, Rockstock and Hamburg also have the capacity to import products. Other than these four oil ports, there are several storage sites with anchoring berths in German coastal and riverside towns.

Pipelines

The majority of crude oil imports into Germany is either directly transported by pipelines or forwarded to pipelines after shipping. Germany's crude oil market primarily runs on three trans-border pipelines: the Transalpine Pipeline (TAL) from Trieste/Italy, the Rotterdam Rhine Pipeline (RRP) from Rotterdam, and Mineralölverbundleitung (MVL), an extension of the Druzhba pipeline from Poland. In 2017, of around 91 Mt of total crude oil imports, 30.7 Mt was transported through TAL; 20.4 Mt through Druzhba; and 16.2 Mt through RRP. The only import pipeline for refined products runs from Rotterdam to the Ruhr and Rhine District (capacity of 250 000 barrels per day [b/d]).

There are four internal pipelines connecting the oil ports of Wilhelmshaven, Brunsbüttel and Rostock to domestic refineries (Figure 10.9). The pipeline connecting Wilhelmshaven and Wesseling (Nord-West Oelleitung [NWO] pipeline) has the largest capacity of around 16.3 Mt (NWO, 2019). Only Rostock/Baltic Sea – Schwedt (MVL pipeline) is capable of reversing flow direction. All crude oil pipelines are privately owned and operated by oil companies.

Several product pipelines also exist, including the 250 000 b/d Rhein-Main-Rohrleitungstransportgesellschaft (RMR) from Rotterdam to Ludwigshafen. The Central Europe Pipeline System of the North Atlantic Treaty Organization (NATO) is also used for the transportation of JET A-1 and the supply of civil airports.

As a part of the European Projects of Common Interest (PCI), the extension of the Druzhba pipeline between the Czech Republic and the Spergau refinery in Germany as well as the capacity expansion of the TAL pipeline between Trieste in Italy and Ingolstadt in Germany featured on the latest PCI list from 2017.

Rhine River

The Rhine River is an essential transportation corridor for moving products by barge from the Amsterdam-Rotterdam area in the Netherlands to German and Swiss customers as well as for transporting petrochemical components or refinery feedstocks. This became especially salient in the autumn of 2015 and once again in October 2018, when an unusually dry season led to very low water levels on the river over an extended period, which caused significant supply problems closely monitored by the administration. River transportation could not easily be replaced by other means in such situations due to capacity limitations on road and rail, given alternative uses; in addition, administrative obstacles, such as different permit conditions for train drivers in different federal *Länder*, posed impediments. The public German stockholding corporation, Erdölbevorratungsverband (EBV) also stores some of its emergency stocks along the Rhine, which in a low-water level situation would need to be transported by other means of transport than barges.

Refineries

Germany has one of the largest refining capacities in Europe. German companies determine how to source their oil supply in line with global oil market trends, with refineries optimised for certain crudes or blends of crudes. The two refineries located in Eastern Germany are mainly oriented towards processing Russian crude.

Germany has 13 refineries located throughout the country with total capacity of 103.02 Mt per year (2 mb per day) at the end of 2017.

Table 10.1 German oil refineries, 2018

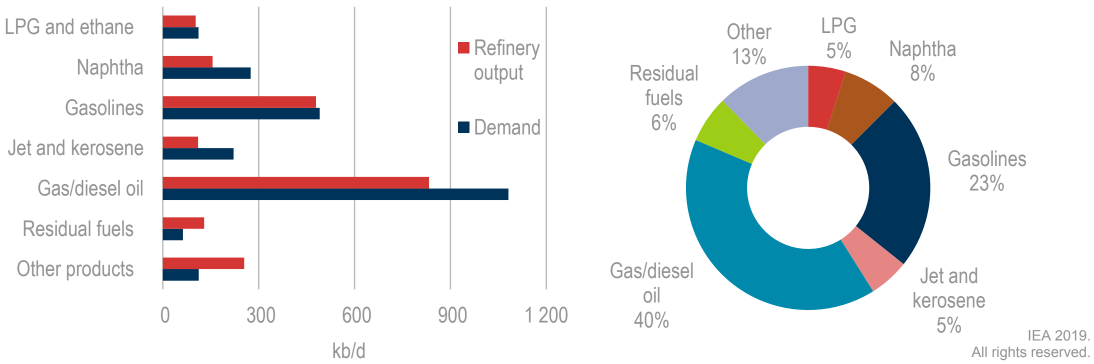
Refinery	Location	*Land*	Capacity (Mt)
MiRO Mineraloelraffinerie Oberrhein GmbH & Co. KG	Karlsruhe	Baden-Württemberg	14.90
Erdoel-Raffinerie Emsland	Lingen	Niedersachsen	4.7
BAYERNOIL Raffineriegesellschaft mbH	Neustadt/Vohburg	Bavaria	10.30
Gunvor Raffinerie Ingolstadt	Ingolstadt	Bavaria	5.00
OMV Deutschland GmbH	Burghausen	Bavaria	3.70
PCK Raffinerie Schwedt GmbH	Schwedt	Brandenburg	11.48
Holborn Europa Raffinerie GmbH	Hamburg	Hamburg	5.15
Rheinland-Raffinerie Werk Godorf	Köln-Godorf	North Rhine-Westphalia	9.30
Rheinland-Raffinerie Werk Wesseling	Köln-Wesseling	North Rhine-Westphalia	7.30
Ruhr Oel GmbH, BP Gelsenkirchen	Gelsenkirchen	North Rhine-Westphalia	12.80
Total Raffinerie Mitteldeutschland GmbH	Leuna-Spergau	Saxony-Anhalt	12.00
Raffinerie Heide	Heide	Schleswig-Holstein	4.20
Nynas GmbH & Co. KG	Hamburg	Hamburg	2.19
Total (Mt)			103.02

Figure 10.9 Map of Germany's oil infrastructure

This map is without prejudice to the status of or sovereignty over any territory, to the delimitation of international prontiers and boundaries and to the name of any territory, city or area.

In 2018, Germany's refinery gross outputs averaged 2.06 mb per day. Gas/diesel oil accounted for 40% – the largest share of total outputs – followed by gasoline with 23% (Figure 10.10). However, as the demands for both gas/diesel oil and gasoline are greater than the domestic outputs, Germany relies on imports.

Figure 10.10 Germany's oil refinery outputs composition, 2018



Note: Includes refinery fuels and excludes refinery losses.
Source: IEA (2019b), *Oil Information 2019*, www.iea.org/statistics/.

Storage

The EBV is responsible for holding compulsory stocks according to the Oil Stockholding Act. As of the end of 2015, Germany had a total oil storage capacity of 62 million cubic metres (mcm), of which over 40% were in caverns (BMWi, 2019). Oil products are mainly stored in above-ground tanks, while most crude oil is stored in underground caverns (EBV, 2019a). Around one-third of above-ground facilities are operated by companies that are independent from refineries (BMWi, 2019). The above-ground storage facilities are fairly distributed across the country, whereas the caverns are primarily located in northern Germany (see oil emergency preparedness and organisation in the section below for more details on emergency oil reserves).

Storage capacity development is reviewed by the administration regularly in co-operation with the EBV and the *Länder*; the EBV holds annual tenders for new capacity and compensates for deficiencies in regional stocks such as in Bavaria. The total capacity of Germany's oil storage has decreased since the last in-depth review (IDR) in 2013, and is expected to continue to gradually decline. In 2016, three new caverns in Wilhelmshaven with a total capacity of 3 mcm were being constructed by EBV; they are planned to be completed by 2021.

Oil emergency policies and organisation

National Emergency Strategy Organisation

The German National Emergency Strategy Organisation (NESO) has a voluntary joint structure that forms a close co-operation among the federal government, the public stockholding corporation EBV and industry to facilitate a systematic crisis management. The key players include the Federal Ministry for Economic Affairs and Energy (BMWi), the

Federal Office for Economic Affairs and Export Control (BAFA), EBV, and supply experts from the oil industry and trade enterprises.

Within the federal government, the BMWi has the lead responsibility for contingency planning and emergency measures, including the release of stocks by the EBV. Industry players collaborate with NESO's Supply Co-ordination Group (KGV) and the Crisis Supply Council (KVR). KGV is mainly responsible for analysing the domestic supply situation and proposing solutions during a crisis while KVR serves as a political adviser to BMWi for implementing emergency measures such as stock releases and other demand restraint measures. KVR also serves as a platform to communicate with business associations. In terms of structure, KGV consists of eight permanent members (five refiners, two traders and a representative of the tank farm industry) and their deputies; KVR consists of the chairman of EBV's supervisory board, his deputy and the chairman of the KGV.

In the event of a crisis, BMWi activates the NESO followed by the convention of KVR, and KGV if necessary. During a non-emergency period, the NESO office co-ordinates regular emergency response exercises that involve BMWi, BAFA, EBV and KGV. As part of the federal and state-level crisis management that concern Germany's critical infrastructure such as energy and communication technology, a nationwide inter-ministerial and interstate civil emergency exercise (LÜKEX) generally takes place every other year.

Emergency response policy

Germany's oil emergency response policies are underpinned by three key pieces of legislation.

The Oil Stockholding Act (Erdölbevorratungsgesetz) regulates the stockholding of oil and refined products to respond to national and international crises. The act also established the German Stockpiling Agency EBV in 1978, which holds the 90-day stockholding obligation, and set relevant rules on stock releases and reporting.

The 1975 Energy Security of Supply Act (Energiesicherungsgesetz) is the legal basis for Germany's demand restraint measures and other regulatory interventions in the oil market. It also provides a reference to German NESO's joint structure based on co-operation; according to Article 8, government authorities can rely on associations (e.g. industry associations) if they agree to participate.

The Oil Data Act (Mineralöldatengesetz) concerns data collection for the implementation of the 1975 Energy Security of Supply Act, regulating how data are collected in line with the IEA International Energy Programme (IEP) and the European Union's rules on information systems and emergency measures in the oil sector. Based on this act, oil trading companies are required to submit data on oil imports and exports, stocks, and the domestic sale of crude oil and refined products to BAFA on a monthly basis in order to monitor the country's oil market supply and prepare for potential oil supply disruptions.

Emergency oil reserves

EBV is tasked with holding emergency stocks of crude oil and oil products at a level that corresponds to at least 90 days of net imports. There are no further stockholding obligations on industry; however, all refiners and oil product importers are obliged to be members of EBV, whose operations are funded by membership fees. BAFA monitors the fulfilment of the stockholding obligation for which EBV must regularly provide the necessary information and data on stocks.

In meeting the required level of emergency stockholding, EBV must assure a regional balance by holding at least 15 days of gasoline and diesel/heating oil above ground in each of Germany's five supply regions. For JET A-1 fuel, EBV must ensure that sufficient stocks are available to major airports, particularly the main hubs of Frankfurt and Munich.

EBV maintains 58 storage caverns at Wilhelmshaven-Rüstringen, Bremen-Lesum, Heide in the state of Schleswig-Holstein, and Sottorf located near Hamburg (EBV, 2019b). For tank storage, EBV usually shares facilities with other parties, and contracts for volumes with the oil industry, which uses the stocks in its normal conduct of business, over periods of one to five years.

The decision to release stocks is prepared within the department of the director-general for energy policy and implemented by the minister of the BMWi via ordinance. The federal chancellery and other selected ministers may also be consulted before the decision to release stock is taken. A maximum 24 hours is required for this decision-making process in case of an IEA collective action. Once the decision is made, it takes approximately three working days for the released ordinance to enter into force, at which point stocks are made available to industry.

When stocks are released, the BMWi consults KVR on issues related to implementation, including the appropriate breakdown of products being released (i.e. the share of crude oil and individual products).

Germany consistently meets the 90-day stockholding obligation and generally holds reserves well above the obligated amount. As of the end of May 2019, Germany held 122 days of net imports, equivalent to 240 mb of oil stocks reserved. Industry stocks (non-obligated) accounted for 31 days of net imports and the remaining 91 days were public stocks.

Oil demand restraint

The German administration has a strong preference for releasing emergency stocks in case of an oil supply disruption. Demand restraint measures are considered in cases of a long-lasting and/or very severe supply disruption; any decision would take into account the negative impacts such measures could have on economic activities more broadly. The precise mix of measures is determined based on circumstances.

Germany has a range of demand restraint measures that can be deployed in case of an oil supply-related emergency. If the federal government determines that the domestic energy supply either is at risk or has been disrupted, a declaration is required to allow demand restraint measures to be activated. Following such a declaration, demand restraint measures can be implemented via ordinance, with possible measures including: imposing or lowering speed limits, Sunday driving bans, prohibitions on the use of vehicles (including aircraft, boats, etc.), and prohibition of motor sports events. If the measures are implemented to meet the obligations of the IEA's IEP, however, a government declaration is not required.

There are also ordinances on the rationing of gasoline, diesel and heating oil. In the case of heating oil, it would require the approval of the Bundesrat given the role of the *Länder* in implementation. The lead time for this whole process is approximately two to three weeks with the exception of transport fuel rationing, which would require a considerably longer period to become operational. In defined crisis situations, the Act on Safeguarding Transport Services allows for a requisition of additional transport services from private companies to allocate oil products according to priority needs.

In addition to BMWi's study on volumetric oil savings from various demand restraint measures, the Federal Office of Civil Protection and Disaster Assistance (BBK) conducted a study to identify the priority services for fuel allocation in emergencies in 2018, which include electricity supply, gas supply, fuel and heating oil supply, and district heating supply (BBK, 2018).

When demand restraint measures are activated, their effectiveness – in terms of volumetric savings – are monitored via the oil industry's monthly statistics reports.

Assessment

Despite the Energiewende, Germany remains heavily dependent fossil fuels, and oil is still the most dominant source of energy, providing almost one-third of TPES in 2018. Germany has a small domestic crude oil production that has been declining with its major oil reserves depleting over the last decade, making the country a heavy importer of oil. In 2018, Germany's total oil net imports were 2 104 kb/d, which is 12% down from a decade ago. This is largely thanks to a decrease in crude oil imports, which dropped by 19% to 1 720 kb/d, while net imports of oil products increased by almost 70% to 384 kb/d. Russia remains the biggest importer of crude oil to Germany, and increasingly so for oil products. Former Soviet Union countries such as Kazakhstan and Azerbaijan are also among the main oil importers to Germany. Other than Russia, European countries, predominantly the Netherlands, Norway, the United Kingdom, Belgium and Austria, are primary trading partner countries. A notable new development is crude oil imports from the United States since 2015, which jumped from almost zero to 79 kb/d in 2018.

The country's oil demand has been stable at an average of 2 416 kb/d for the last ten years. The transport sector remains the largest oil-consuming sector, accounting for more than half of the total oil consumption, and its share has been growing with demand for diesel going up over the last decade. Thanks to increasingly competitive renewable energies, oil consumption for power generation is almost phased out and that for heat is falling. However, the transport sector remains a big challenge for Germany. To promote the transport sector's low-carbon transition, the government has been providing various financial supports to switch to alternative fuels. The environmental bonus scheme for electric cars and the federal government's subsidy on low-carbon fuels such as CNG and hydrogen and their charging stations have all contributed to the recent growth of Germany's EV market.

To further accelerate decarbonisation of the transport sector, the current fuel tax system can be improved. Transport fuels are heavily taxed but given Germany's historical focus on dieselisation, the tax rate on diesel is still considerably lower than that on gasoline. To fully capture the cost of local air pollution from diesel consumption and encourage a switch to low-carbon fuels, the differential tax rates on fuels can be recalibrated. In a similar vein, Germany's current level of tax on heating oil (light fuel oil) does not give much support on decarbonising the heating sector.

As one of the leaders of advanced industrial technology, the German industry is working on developing innovative low-carbon synthetic fuels (or e-fuels) that can be applied to conventional engines and would spare the need to deploy special infrastructure otherwise needed for EVs and/or hydrogen vehicles. While such research and development initiatives are commendable, the government should collaborate with the industry on restructuring domestic refineries to produce cleaner fuels, thereby establishing a complete domestic supply chain of low-carbon fuels. Such investments would result in a more sustainable and secure energy system in Germany.

On security of oil supply, Germany's liberalised and competitive oil market helps with efficient allocation of products. Following the recommendation from the last IDR, the federal government created the MTU in 2013. By disclosing fuel price information to consumers, the MTU can enhance the transparency as well as the competitiveness of the German oil market. Additionally, Germany's oil supply infrastructure is well connected and maintained to ensure a solid security of supply. In recent years, however, there have been recurring incidents in one of the major transnational oil supply routes – the Rhine River. The extreme dry seasons in the autumn of 2015 and 2018 lowered the water level, disabling water transportation. With limited alternatives during extended periods of dry weather, the federal government has decided to release emergency stocks to minimise the impacts of this supply disruption. As climate change and associated extreme weather events are likely to increase in terms of both frequency and intensity, it is essential that Germany, a heavy importer of oil, remain prepared for potential supply disruptions caused by natural disasters.

For that, Germany has solid oil security policies and complies with the regulations of the IEA and European Union concerning oil stockholding. Within the federal government, the BMWi is in charge of ensuring energy security and emergency matters while emergency oil stocks are held by the public oil stockholding corporation, EBV. The country also has a comprehensive set of demand restraint measures that can be implemented in case of an emergency but no potential for other options such as a surge in oil production or fuel switching. Hence, it is critical that Germany maintain strong policies on oil security via both domestic and international measures.

Recommendations

The government of Germany should:

- ☐ Recalibrate the tax structure for conventional fuels in the transport and heating sectors, to take account for their environmental impact, and strengthen incentives and financial support for alternative fuels.
- ☐ Together with industry, design a policy to help transition the refinery sector to produce low- and zero-emission fuels. The policy should set goals, incentives and obligations for the sector.
- ☐ Design policies to promote a modal shift for passengers towards public transport.

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11. Nuclear

Key data

(2018 provisional)

Number of reactors: 7 reactors

Installed capacity (2017): 10.8 GW

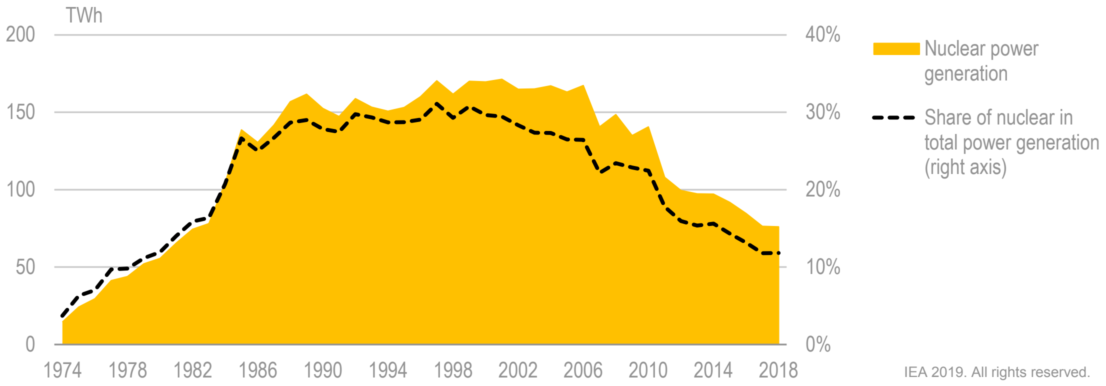
Electricity generation: 76.0 TWh, -49% since 2008

Share of nuclear: 11.8% of electricity generation

Overview

The decision to phase out all nuclear power generation by 2022 is one of the core objectives in the German energy transition. It was taken in 2011 after the Fukushima Daiichi accident. Since 2011, ten nuclear power plants (NPPs) with a net capacity of 11 gigawatts (GW) have been shut down. Seven NPPs remain in operation until 2022 at the latest. In 2018, nuclear power generated 76.0 terawatt-hours (TWh). This accounted for around 12% of Germany's total power generation (Figure 11.1).

Figure 11.1 Nuclear power generation and share in electricity generation, 1974-2018



Nuclear power increased rapidly from the 1970s to the 1990s, but since 2005, generation has fallen from around 30% of total power generation to 12% in 2018.

Source: IEA (2019a), *World Energy Balances 2019*, www.iea.org/statistics/.

The share has fallen from 30% two decades earlier and is expected to drop to zero after 2022 in line with the phase-out decision. Despite the phase-out plans, there will remain nuclear activities in Germany associated with dismantling and decommissioning of plants, waste management, nuclear safety and waste management research, and nuclear non-power applications.

Industry structure

As of 2017, Germany had an installed nuclear power capacity of 10.8 GW (seven reactors), producing 76.3 TWh (11.8% of Germany's electricity share). Compared with 2007 values, this represents a reduction of 46%. Since the Fukushima accident in 2011, nine reactors have been decommissioned (9.7 GW), eight of them immediately after the enactment of the 13th Amendment of the Atomic Energy Act in August 2011.

Four companies are in charge of the operation of the remaining nuclear fleet: E.ON (since 2016, through its subsidiary PreussenElektra), RWE, Vattenfall and EnBW. All NPPs are privately owned (Table 11.1).

Following the Fukushima events, the Reactor Safety Commission (RSK) evaluated the safety of the 17 operating reactors at the time and concluded that compared with the Fukushima Daiichi NPP, the level of safety of German plants was sufficiently robust to face loss of external electricity supply and flooding events. Further robustness tests revealed that no uniform findings could be established based on the initial plant design or age. Those plants with initially lesser design requirements were upgraded with partly autonomous emergency systems to ensure vital safety functions (IAEA, 2019a). European Nuclear Safety Regulators Groups (ENSREG) workshops conducted in 2013 and 2015 yielded similar conclusions (ENSREG, 2015). Recently, an International Atomic Energy Agency (IAEA) mission found that Germany had strong practices and processes in place to ensure comprehensive regulatory oversight. Opportunities for further enhancement were identified in the field of decontamination and decommissioning (D&D), activities that should intensify in the coming years (IAEA, 2019b).

The Atomic Energy Act stipulates that German NPPs must perform periodic safety reviews every ten years following the national Nuclear Safety Standards Commission (KTA) standards. Before 2022, only two plants will conduct a comprehensive safety assessment: Gundremmingen C and Brokdorf.

Besides the NPPs, there are seven research reactors and three other nuclear facilities in operation in Germany (Figure 11.4). They are part of the research and industrial capabilities developed in the nuclear field over the last decades:

- nuclear fuel production facility for light water reactors in Lingen
- enrichment facility by centrifugation in Gronau
- nuclear waste conditioning facility in Gorleben.

Table 11.1 Status of the German nuclear fleet, 2018

NPP	Type	Grid connec-tion year	Maximum power output (MW)	Operator	Owner	Gross power generat-ion (GWh)	Closure date according to the 13th Amendment of the Atomic Energy Act
Biblis A*	PWR	1975	1 167	RWE	RWE	0	2011
Neckarwestheim 1*	PWR	1976	785	EnBW	EnBW	0	2011
Biblis B*	PWR	1977	1 240	RWE	RWE	0	2011
Brunsbüttel*	BWR	1977	771	Vattenfall	67% Vattenfall 33% PreussenElektra	0	2011
Isar 1*	BWR	1979	875	Preussen Elektra	PreussenElektra	0	2011
Unterweser*	PWR	1979	1 345	Preussen Elektra	PreussenElektra	0	2011
Philippsburg 1*	BWR	1980	890	EnBW	EnBW	0	2011
Krümmel*	BWR	1984	1 346	Vattenfall	50% Vattenfall 50% PreussenElektra	0	2011
Grafenrheinfeld*	PWR	1982	1 275	Preussen Elektra	PreussenElektra	0	2015
Gundremmingen B*	BWR	1984	1 284	RWE	75% RWE 25% PreussenElektra	0	2017
Philippsburg 2	PWR	1985	1 402	EnBW	EnBW	10 323	2019
Gundremmingen C	BWR	1985	1 288	RWE	75% RWE 25% PreussenElektra	9 874	2021
Grohnde	PWR	1985	1 360	Preussen Elektra	83.33% PreussenElektra 16.67% SWB	10 339	2021
Brokdorf	PWR	1986	1 410	Preussen Elektra	80% PreussenElektra 20% Vattenfall	9 838	2021
Isar 2	PWR	1988	1 410	Preussen Elektra	75% PreussenElektra 25% SWM	11 477	2022
Emsland	PWR	1988	1 335	RWE	87.5% RWE 12.5% PreussenElektra	10 915	2022
Neckarwestheim 2	PWR	1989	1 310	EnBW	EnBW	9 099	2022

* NPPs that have already shut down.

Notes: MW = megawatts; GWh = gigawatt-hours; PWR = pressurised water reactor; BWR = boiling water reactor.

Nuclear phase-out

After the 1998 elections, the German government concluded an agreement with the main German utilities to phase out the use of nuclear energy for the commercial generation of electricity. The Atomic Energy Act was amended accordingly in 2002. As a result, the construction of new nuclear plants was forbidden and residual electricity production volumes were allocated among the remaining NPPs according to a maximum lifetime of 32 years. Two plants were shut down, in 2003 (Stade) and 2005 (Obrigheim).

The new elected German government in 2009 decided to support the role of nuclear energy as a “bridging technology” towards a low-carbon future. In December 2010, by means of the 11th Act Amending the Atomic Energy Act, the government granted lifetime extensions to the 17 nuclear reactors (8 years to 7 reactors and 14 years to 10 reactors) in operation at the time. The lifetime extensions were converted into electricity volumes for each plant. Additionally, a nuclear fuel tax was imposed. Between January 2011 and December 2016, nuclear operators paid a EUR 145 levy for every gramme of fissile material used in their reactors.

The Fukushima accident in March 2011 represented a new shift in German energy policy with regard to nuclear power. Supported by the RSK and in close collaboration with the states (*Länder*), the safety of all German NPPs was reviewed. Also, through an Ethics Commission on Secure Energy Supply, a dialogue was established with the public on the risks involved in the use of nuclear power and the possibility to accelerate the energy transition with greater reliance on renewable energy. Taking into account the assessments of the RSK and following the Ethics Commission on Secure Energy Supply, the government decided to accelerate the phase-out of nuclear power. The 13th Amendment of the Atomic Energy Act was enacted in August 2011. This new amendment revoked the lifetime extension and residual electricity volumes introduced by the 11th Amendment. Eight reactors (Neckarwestheim 1, Phillipsburg 1, Biblis A and B, Isar 1, Unterweser, Brunsbüttel and Krümmel) lost their operating licences with immediate effect, and remaining nuclear capacity should be phased out by the end of 2022 at the latest (see Table 11.1 for a detailed closure calendar). According to a survey published by the Institute of Advanced Sustainability Studies in 2017, the nuclear phase-out decision still receives 68% of support among the German population (IASS, 2017).

The accelerated nuclear exit was also the beginning of a series of legal procedures between nuclear operators and the German government. The utilities claim around EUR 20 billion (Deutsche Welle, 2016) in compensation for the losses incurred that have, in some cases, been granted by the German cabinet (Deutsche Welle, 2018).

Furthermore, in 2017, the Federal Constitutional Court declared the nuclear fuel tax introduced by the 11th Amendment of the Atomic Energy Act unconstitutional. In consequence, the German government has to reimburse up to EUR 6.3 billion to the nuclear operators, the equivalent of taxes paid between 2011 and 2016 plus interest (Deutsche Welle, 2017).

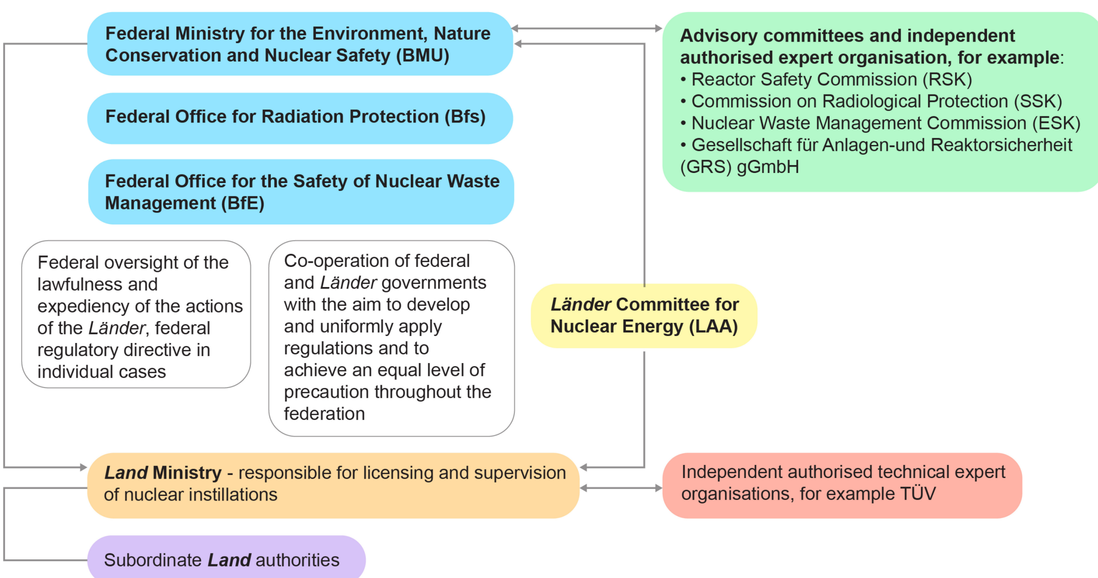
Additional lawsuits related to nuclear waste management issues have also been reported (Appunn, 2015). The agreement reached between the operators and the federal government through the Act on the Reorganisation of Responsibility in Nuclear Waste Management has led to the cancellation of several of these legal procedures (IAEA, 2018).

Institutions

In 1986, the federal government assigned by organisational decree the responsibility for nuclear safety and radiation protection to the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). As Germany is organised as a federal state, the licensing procedure for operation and decommissioning and continuous regulatory supervision of nuclear facilities is the responsibility of individual federal states. BMU is tasked with the "oversight of lawfulness expediency" of the actions of the *Länder*. The effective co-operation between the *Länder* and the federal government is ensured through the Länder Committee for Nuclear Energy (LAA). The BMU has two main subordinate authorities that provide technical and scientific support: the Federal Office for the Safety of Nuclear Waste Management (BfE) and the Federal Office for Radiation Protection (BfS).

The BfE, established in 2014, is the licensing and supervisory authority for radioactive waste management.[15] With the introduction of the Act on the Organisational Restructuring in the Field of Radioactive Waste Management in June 2017, the BfE is also in charge of the licensing and supervision of waste management facilities and will regulate the site selection process of final disposal facilities, in particular the one for heat-generating waste.

Figure 11.2 Organisational structure of Germany's nuclear regulatory oversight



Source: Government of Germany.

Since 2017, BfS's scope has been redefined to provide support on radiation protection, medical research and environmental surveillance at a federal level.

The BMU also receives regular advisory support from several committees and technical expert organisations. The committees are independent and their members reflect the entire spectrum of scientific and technical opinions. At the *Länder* level, independent technical organisations (TÜV) are also consulted.

[15] This includes transport and handling.

Nuclear waste management reorganisation

Before 2017, and in line with the Atomic Energy Act and the "polluter pays" principle, nuclear operators in Germany were obliged to build up provisions in order to cover the costs associated with dismantling a plant and the management of nuclear waste generated during its operating lifetime. Conditioning, transport, interim storage and final disposal of the nuclear waste were also part of expenses borne by nuclear operators.

In addition, Germany was the only country where operators, in order to cover future liabilities associated with the use of nuclear technology for power generation, were building such provisions without specific regulation by the government. German operators used such provisions at the time to acquire tangible assets such as power plants whose value could change in the long term.

In 2011, the German Federal Court of Auditors (Bundesrechnungshof) noted that the federal government lacked expertise to judge whether provisions made by the utilities were sufficient, posing considerable risk to the federal budget (Appunn and Wehrmann, 2017).

On behalf of the Federal Ministry for Economic Affairs and Energy (BMWi), auditors from Warth & Klein Grant Thornton (WKGT), assessed the sums put aside by operators for back-end liabilities. The results of the so-called "Stress Test" were published in October 2015 and revealed that the provisions would be sufficient to pay for the back-end liabilities of NPPs. However, future costs could exceed utilities' estimates depending on discount rates and price escalation assumptions. In 2014, for instance, nuclear companies had secured EUR 38 billion (EUR 22 billion for dismantling and EUR 16 billion for waste management). The total assets from nuclear companies were estimated at EUR 83 billion (BMWi, 2015), values that were also judged as acceptable to face long-term liabilities in light of overall uncertainties.

Following the "Stress Test" results, the federal cabinet decided in 2015 to set up the Commission to Review the Financing for the Phase-Out of Nuclear Energy. This commission was tasked to ensure the application of the "polluter pays" principle and the protection of the taxpayer from the liabilities related to the nuclear back-end activities without jeopardising the economic situation of power companies. At that time, some German utilities were in the middle of a major restructuring process in order to adapt to the nuclear phase-out decision and weaker market conditions for conventional generation because of increasing market shares of electricity from renewable energy sources. These corporate reorganisations could also lead to a situation of "diluted responsibility" between parent and child companies in terms of nuclear waste management obligations.

Taking all these aspects into account, the commission advocated for a more transparent model with a clear separation of responsibilities between operators and state, where operators would have extended liability and the federal government would have full competences in financing and operating waste management activities.

To this end, the Act on the Reorganisation of Responsibility in Nuclear Waste Management (hereinafter referred to as the Reorganisation Act) was enacted on 16 June 2017. This act sets out a new model in terms of responsibilities for decommissioning of NPPs and for nuclear waste management. Nuclear operators will remain responsible for the financing and operation of the D&D of nuclear facilities and the correct packaging of nuclear waste. On the other hand, the federal government remained responsible for the storage and final disposal of nuclear waste, and assumed responsibility for financing. On 3 July 2017, nuclear operators transferred EUR 24 billion to the external state-owned Nuclear Waste Disposal Fund (KENFO), which finances nuclear interim storage and waste disposal, and is organised as a foundation under public law and supervised by a board of trustees representing members of parliament and the government. The final amount is a combination of a base rate of EUR 17 billion (determined by the "Stress Test") and an additional 35.5% risk premium (around EUR 7 billion) that will exempt nuclear operators from additional payments in case future costs related to storage exceed current projections.

From an operational perspective, the organisation responsible for the planning, construction, operation and closure (i.e. project implementer) of final disposal facilities is the Federal Company for Final Disposal (BGE). The equivalent organisation for the interim storage facilities is the Company for Interim Storage (BGZ). In August 2017, BGZ took control of the heat-generating waste facilities at the Ahaus and Gorleben sites. In January 2019, the operation of the 12 on-site spent fuel facilities was also transferred. In January 2020, the interim storage facilities with low- and medium-active waste with negligible heat generation will also be transferred to BGZ. Both BGE and BGZ are federal state-owned companies. Prior to 2017, BfS, with the support of the German Society for the Construction and Operation of Waste Repositories (DBE),[16] performed all the activities related to final disposal, project management and supervision, while nuclear operators, through GNS[17], were in charge of interim storage activities (see Table 11.2).

Table 11.2 Organisational restructuring in the field of radioactive waste management

	Before 2017		After 2017 (still in process)	
	Supervisor	*Implementer*	*Supervisor*	*Implementer*
Repository sites	BfS	DBE	BfE	BGE
Interim storage facilities		GNS		BGZ

Moreover, two additional parts of the Reorganisation Act provide further details about the new obligations for nuclear companies: the Transparency Act and the Extended Liability Act.

According to the Transparency Act, nuclear operators must report once a year to the Federal Office for Economic Affairs and Export Control (BAFA) on the provisions made to fulfil D&D obligations and on the liquid funds available for this purpose.

The Extended Liability Act ensures that NPP operators bear liability in case of corporate restructuring. Parent companies remain indefinitely[18] liable for the nuclear operators they control. This act is intended to prevent the risk of termination or dilution of corporate

[16] Founded in 1979, DBE was owned by both the federal government (25%) and the nuclear companies through the Society for Nuclear Service (GNS) (75%). DBE was entrusted with the task of implementing site selection procedures for a final deep geological repository, particularly for heat-generating waste. On behalf of the federal state (through co-operation agreements with the BfS), DBE co-ordinated the executive planning and activities related to nuclear waste repositories such as Asse-II, Morsleben, Gorleben and Konrad.

[17] Joint venture set up in 1977 and owned by the German nuclear companies. Under the Reorganisation Act, GNS is redefining its scope and transferring some of its activities to BGZ. It will remain as the main cask manufacturer.

[18] Until the clean-up process is completed.

liabilities due to changes in the ownership structure (i.e. spin-off of nuclear assets into separate companies).

Overall, the Reorganisation Act provides long-term legal certainty for both the federal government and the utilities, and puts an end to a number of legal disputes between energy companies and the state regarding matters linked to nuclear waste management and the nuclear phase-out.

Nuclear waste management

As described above, since 2017, the federal government bears all the organisational, operational and financial responsibilities in relation to the interim storage and final disposal of nuclear waste. Nuclear waste management activities are supervised by BfE and implemented by BGE and BGZ.

Two main criteria are commonly used to sort nuclear waste: the radioactivity level and the decay lifetime. Based on the radioactivity level, nuclear waste can be classified as:[19]

- High-level radioactive waste (HLW): this includes spent nuclear fuel (SNF) and the products from its reprocessing. HLW has a long decay period and generates important quantities of decay heat that have to be continuously removed from the storage and disposal facilities. Since 2005, the transport of spent fuel to reprocessing plants is prohibited in Germany.
- Intermediate-level radioactive waste (ILW): for instance, most of the waste generated during D&D activities. ILW may have short or long decay periods. The decay heat generated is lower compared with HLW.
- Low-level waste (LLW).

The German strategy is to dispose of all types of radioactive waste in deep geological formations (final disposal facilities or repositories). In this sense, the radioactivity level is not an important technical parameter compared with the inventory level and heat generated during the decay process. Hence, radioactive waste in Germany is divided into heat-generating waste (HGW) and negligible heat-generating waste (NHGW). HGW corresponds to HLW and part of ILW. NHGW involves established categories of LLW and the major part of ILW.

Before its final disposal, radioactive waste is kept in interim storage facilities. These facilities can be built on-site (i.e. in the NPPs for mainly spent fuel management purposes) or off-site where nuclear waste management activities are centralised. Their operating licence is usually for 40 years. Longer time periods may require additional studies.

In 2015, BMU released a first draft of the "Programme for the responsible and safe management of spent fuel and radioactive waste" (BMU, 2015a). This publication offers a comprehensive analysis of the current nuclear waste inventory as well as future projections necessary to evaluate current capabilities and the potential expansion of waste management infrastructure (see Table 11.3).

[19] This classification may vary from one country to another depending on national criteria.

Table 11.3 Germany's nuclear waste inventory

	As of 31 December 2014	Total projected inventory
HGW	1 020 casks*	1 900 casks
NHGW	117 000 cubic metres (m^3)	600 000-620 000 m^3

*An additional 4 258 tonnes were in the NPPs' storage pools.

Source: BMU (2015), "Programme for the responsible and safe management of spent fuel and radioactive waste".

Interim storage

Germany has numerous interim storage facilities in operation spread all over its territory. They are located on-site in the NPPs as well as off-site.

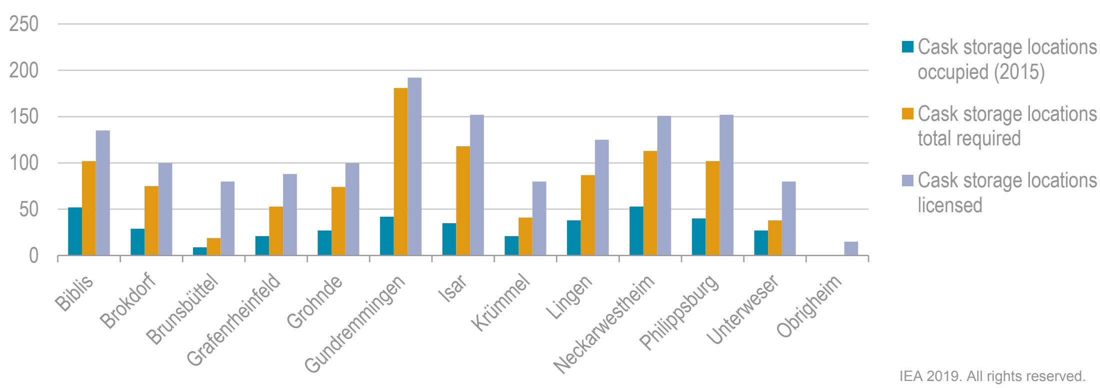
According to the BfE (BfE, 2019a), there are 30 interim storage facilities for NHGW:

- 11 *Länder* collecting depots
- 6 central facilities
- 13 for research, medicine and industrial applications.

The HGW interim storage facilities include 3 central off-site facilities and 12 on-site facilities. A 13th on-site facility at Obrigheim NPP is being licensed. As indicated above, these on-site facilities will carry – for a licensed period of 40 years – the SNF coming from the operation of the NPPs until a final disposal site is selected and built (see below section on final disposal). At the end of 2015, 394 CASTOR casks were safely stored in the German NPPs (see Figure 11.3).

The most important central off-site interim storage sites are Ahaus, Gorleben and Zwischenlager Nord, where both NHGW and HGW facilities are located.

Figure 11.3 German NPPs' on-site interim storage capacities



Source: BfE (2019a), "Interim storage facilities".

Final disposal

According to German legislation, all types of nuclear waste are to be finally disposed in underground repositories for an unlimited period of time and in safe and maintenance-free conditions. Germany has already accumulated some experience in selecting and exploiting several repository facilities for NHGW (Konrad, Asse II and Morsleben) and is exploring a potential site for HGW (Gorleben).

- **Konrad** is an abandoned iron mine located near Salzgitter. It is currently in the process of being converted into a final repository. A definitive licence for the construction and operation of the repository was granted in 2007. It is the first waste management facility in Germany that has been through a full licensing process before its exploitation. The Konrad facility has the approval to take 303 000 m^3 of NHGW from the D&D of NPPs as well as from industrial, medical and research applications. Operation is expected to begin in 2027. NHGW emplacement is not supposed to exceed 40 years (OECD/NEA, 2016).
- **Asse II** is a former potassium and rock salt mine. Between 1967 and 1978, around 47 000 m^3 of NHGW were emplaced. The presence of saline solutions and groundwater combined with stability problems led to the decommissioning of the repository. Since 2013, the retrieval of Asse II waste is legally an option unless the executory works are unjustifiable for safety and radiological reasons. According to current planning, retrieval cannot start before 2033 although efforts are being undertaken to allow for an earlier start. This process will generate a total of 200 000 m^3 of NHGW to be conditioned and stored safely on-site until a new emplacement is defined. The future HGW repository site could be a candidate.
- **Morsleben** repository received NHGW from 1971 to 1991 and from 1994 to 1998, 36 754 m^3 in total. Its permanent operating licence is still effective but the condition of the site is considered unreliable. Stabilisation work is needed before sealing the repository for the long term.
- The **Gorleben** exploration mine has been studied as a potential site for an HGW final repository since 1977. Exploratory works were terminated in 2013 with the introduction of the Site Selection Act (StandAG; see below). Nevertheless, Gorleben is still kept as a potential repository site as long as it meets the requirements and criteria laid down in the StandAG. NHGW and HGW interim storage facilities are currently exploited at this site.

Site Selection Act

On 27 July 2013, the act for the selection of a final disposal site for the HGW – the so-called Site Selection Act (StandAG) – was adopted. The federal government then established the Commission on Storage of High-Level Radioactive Waste for the evaluation of the StandAG, and several proposals were submitted for its amendment. After evaluation by the Bundestag and Bundesrat, the recommendations were considered in the Reorganisation Act (in force since 16 June 2017) and in the Act Amending the StandAG, which was finally enacted on 16 May 2017.

The amendment of the StandAG sets out the criteria and decision bases for the site selection of the HGW final disposal. It prescribes an open-ended selection process, starting from a “blank map” of Germany. Rock types such as rock salt, clay and crystalline rock are mentioned. These are the three rock host types for which research and development (R&D) activities have been already carried out. The associated results, including those for the Gorleben site (see above), can be considered in the exploration and final assessment of the potential locations.

The site selection procedure consists of three phases:

- phase 1: determination of the siting regions for surface exploration
- phase 2: surface exploration and proposal for underground exploration
- phase 3: underground exploration, siting proposal and decision on the site.

As stipulated by the Reorganisation Act, the site selection procedure will be implemented by BGE; BfE will be in charge of its supervision (Table 11.2). The site selection process is currently in phase 1 (BMU, 2019).

The goal is to find an HGW disposal site in the Germany territory that will ensure safe enclosure for a million years. Consequently, a participative, science-based, transparent, self-critical and learning process is at the core of the StandAG. The principles for public consultation, for which BfE takes responsibility, are clearly depicted in the main text of the StandAG. At the end of each phase of the selection process, the public can offer its opinion or raise objections that will be treated in discussion meetings. In addition, since October 2016, the National Citizens' Oversight Committee has been acting as an independent observer of the site selection process, while also acting as a mediator if conflicts arise.

The final decision on the site for HGW final repository is expected to be taken by 2031. The decision will be followed by a licensing procedure according the Atomic Energy Act. The disposal facility is foreseen to be commissioned by 2051.

Cost estimations for storage and final disposal

In line with the Reorganisation Act, the financing of future final disposal facilities and associated works is borne by the federal government. Given the long time horizon associated with this type of activity, combined with the lack of experience from completed projects, cost estimations are subject to significant uncertainties

The 2015 BMU report on the "Cost and financing of the disposal of spent fuel and radioactive waste" (BMU, 2015b) provides a first estimation of the investment related to the German repositories. According to this publication, the StandAG site selection process (EUR 2 billion) and the construction, operation and decommissioning of an HGW final disposal facility (EUR 7.7 billion) could represent altogether EUR 9.7 billion. Members from the Commission on Storage of High-Level Radioactive Waste indicated that these costs could even rise up to EUR 50 billion or EUR 70 billion over the next decades (Appunn and Wehrmann, 2015). The cost of the NHGW Konrad repository could be in the region of EUR 7.5 billion. This evaluation takes into account the expenses incurred, up to 2015, for the planning and exploration of the site as well as the projected costs of construction, emplacement operation and final closure of the facility.

The 2015 BMU report also indicates that the costs associated with the retrieval and disposal of Asse II mine waste (EUR 5 billion) and to the stabilisation works and final enclosure of Morleben site (EUR 1.4 billion[20]) could together represent EUR 6.4 billion.

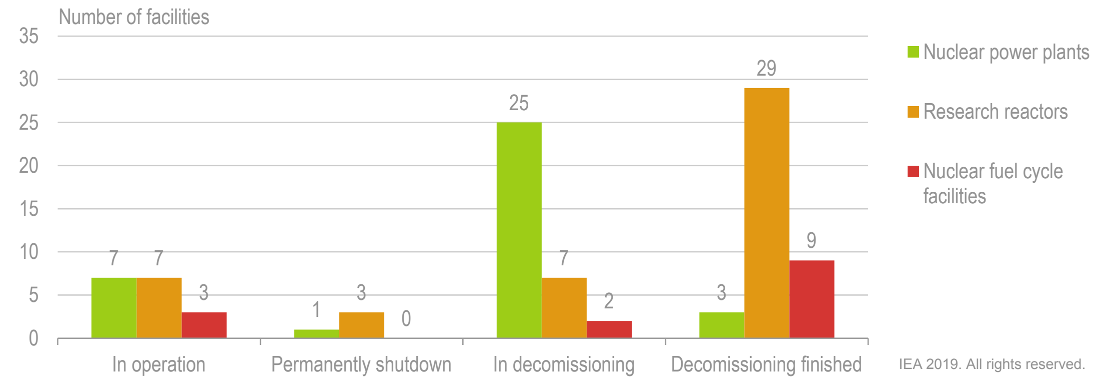
Decommissioning

As established by the Reorganisation Act, German operators bear all the expenses associated with the D&D works as well as with the conditioning and packaging of all the waste generated during these activities (including transport to the interim storage facilities). The federal government is responsible for the D&D of publicly owned research reactors and of the Greifswald and Rheinsberg NPPs. These NPPs (six units in total)

[20] These are 2015 estimations that do not include ±30% of contingencies, the costs of dismantling the installations above ground, and the cost of compensatory and substitute measures, which are difficult to quantify.

were taken over from the former East German state and did not find private owners after Germany's reunification. The public company in charge of their decommissioning is Entsorgungswerk für Nuklearanlagen GmbH (EWN).

Figure 11.4 Nuclear facilities in Germany, as of April 2019



Source: BfE (2019b), "Nuclear installations in Germany", www.bfe.bund.de/EN/ns/ni-germany/ni-germany_node.html.

As of April 2019, 29 nuclear reactors, including prototypes and experimental reactors, have been permanently shut down in Germany: 24 are currently being dismantled and returned to "greenfield" status, 1 facility is in "safe enclosure" and 3 have already been returned to "greenfield" status and released from regulatory control. Including research reactors and nuclear fuel cycle activities, the number of facilities already decommissioned in Germany is 41. From the ten reactors shut down since 2011, all of them have been granted with a decommissioning license except for Krümmel NPP. Of the seven reactors that remain in operation, all have applied for a decommissioning licence except for Gundremmingen C and Isar 2 (Table 11.4).

The D&D approach retained by Germany is "immediate dismantling". One of the main advantages of this approach is that D&D operations can be carried out by a workforce that is highly knowledgeable about the facility, which reduces overall costs (OECD/NEA, 2002). After the final shutdown of the plant and before a decommissioning licence is granted – the so-called post-operational phase – most of the activities are essentially devoted to the planning of D&D, completion of the licensing process and removal of the radioactive operational waste (RWE, 2017). The SNF is enclosed in CASTOR casks to be then stored in the interim on-site facilities. Once the decommissioning licence has been granted by the competent licensing authority of the *Länder* and all the operational waste has left the plant, clean-up activities can begin. According to the estimations of various German operators, the full decommissioning process of a NPP could take 15-20 years (WNA, 2017).

Along with EWN, private companies such as EnBW, RWE, PreussenElektra and Kernkraftwerk Brunsbüttel[21] have been involved in the decommissioning of NPPs and have several ongoing projects. Since the late 1960s, decommissioning licences for nuclear facilities have been granted steadily, which has contributed to building up extensive experience in the D&D field.

[21] Held by Vattenfall GmbH (66.6%) and PreussenElektra GmbH (33.3%).

Table 11.4 Applications and licences for decommissioning due to nuclear phase-out (as of April 2019)

NPP		Permanent shutdown	First application for decommissioning	First licence granted for decommissioning
Isar 1	KKI 1	06.08.2011	04.05.2012	17.01.2017
Unterweser	KKU	06.08.2011	04.05.2012	05.02.2018
Biblis A	KWB A	06.08.2011	06.08.2012	30.03.2017
Biblis B	KWB B	06.08.2011	06.08.2012	30.03.2017
Brunsbüttel	KKB	06.08.2011	01.11.2012	21.12.2018
Neckarwestheim 1	GKN 1	06.08.2011	24.04.2013	03.02.2017
Philippsburg 1	KKP 1	06.08.2011	24.04.2013	07.04.2017
Krümmel	KKK	06.08.2011	24.08.2015	-
Grafenrheinfeld	KKG	27.06.2015	28.03.2014	11.04.2018
Gundremmingen B	KRB B	31.12.2017	11.12.2014*	19.03.2019
Philippsburg 2	KKP 2	In operation	18.07.2016	-
Grohnde	KWG	In operation	26.10.2017	-
Gundremmingen C	KRB C	In operation	-	-
Brokdorf	KBR	In operation	01.12.2017	-
Isar 2	KKI 2	In operation	-	-
Emsland	KKE	In operation	22.12.2016	-
Neckarwestheim 2	GKN 2	In operation	18.07.2016	-

*Dismantling of components

Source: BMU (2019), "Nuclear regulatory issues and main developments in Germany", www.bfe.bund.de/SharedDocs/Downloads/BfE/EN/reports/kt/germany-nuc-reg-issues.pdf?__blob=publicationFile&v=9.

Cost estimations for decommissioning

A 2015 BMU report provides cost figures related to D&D activities in Germany. The total costs arising from the dismantling of publicly owned reactors (i.e. research reactors and Greifswald and Rheinsberg NPPs) is estimated, from 2013 until 2080, at EUR 5.7 billion[22] (around EUR 2 billion for dismantling and EUR 3.7 billion for the conditioning, storage and transport of the generated waste) (BMU, 2015a). The figures, however, are subject to important uncertainties.

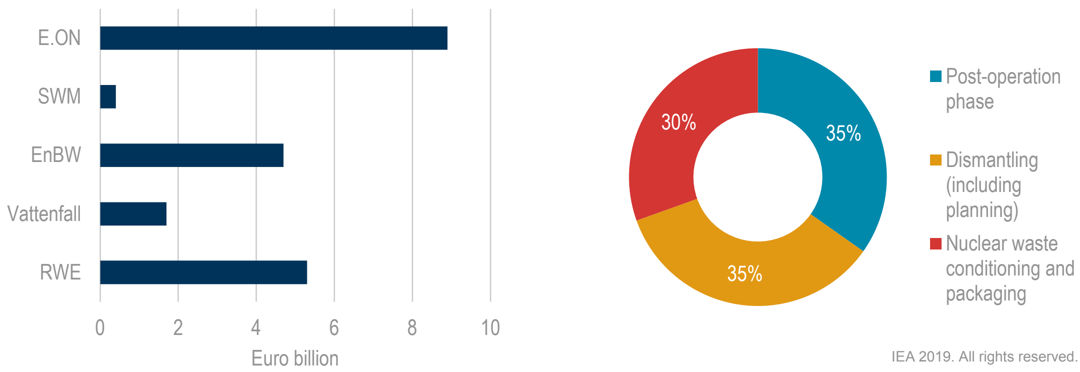
With regard to the privately owned NPPs, the 2015 BMU report estimates cost of decommissioning and waste management (excluding disposal) at EUR 34 billion (BMU, 2015a). This number is close to the amount that the nuclear utilities had already built up in 2014, EUR 38 billion, from which EUR 22 billion corresponded to D&D activities and the conditioning and transport of the waste. In their "Stress Tests", WKGT auditors found this sum higher than the international average. Cost reduction opportunities of EUR 6 billion were also identified.

In addition, BAFA performed in 2018 its first audit according to the Transparency Act on the provisions made by the nuclear operators for their D&D activities. The results of the audit show that there are no grounds for objection regarding the calculation of the amount of the provisions (EUR 21 billion) (Figure 11.5) made by the companies and that

[22] Based on 2012 prices.

there are no indications to suggest that the companies might not meet the requirements related to the dismantling the NPPs.

Figure 11.5 Build-up in provision for D&D by company and activity



Source: BAFA (2018), "Bericht der Bundesregierung nach § 7 des Gesetzes zur Transparenz über die Kosten der Stilllegung und des Rückbaus der Kernkraftwerke sowie der Verpackung radioaktiver Abfälle – Berichtsjahr 2017" [Report by the Federal Government pursuant to Section 7 of the Transparency Act on the Costs of decommissioning and Dismantling Nuclear Power Plants and the Management of Radioactive Waste - reporting year 2017], http://dipbt.bundestag.de/doc/btd/19/062/1906223.pdf.

Nuclear research and competencies

Around 21% of the federal government's budget for energy-related R&D is allocated to nuclear research activities (IEA, 2019b). The funding is in the range of EUR 150 million to EUR 200 million per year and it has remained at a stable level despite the nuclear phase-out decision in 2011. In fact, Germany does not foresee phasing out nuclear technology and carries out research in domains such as nuclear safety, waste management and disposal, basic sciences, and non-power applications such as materials behaviour and fusion energy.

Research activities in the field of waste management and disposal aim at scientifically supporting the site selection procedure defined in the StandAG. The collection of data for the long-term safety assessment of the different host rock formations (i.e. rock salt, clay and crystalline rock) is essential. Decommissioning research activities are focused on the development of standardised procedures and remote-operated decontamination techniques that will reduce radiation exposure and costs. In the field of reactor safety, Germany seeks to ensure sufficient skills for the safe exploitation of the remaining life of the existing fleet and for the assessment and further improvement of safety of foreign NPPs and reactor designs. Methods for reliable safety analysis with numerical tools, material characterisation in nuclear environments, and enhanced understanding and modelling of severe accident phenomena are main research activities in this field (OECD/NEA, 2018).

One of the main objectives pursued with the research, development and demonstration budget allocation strategy is to maintain and reinforce nuclear expertise in domains that are critical for the future of nuclear in Germany, such as waste management and disposal, and nuclear safety. Moreover, research facilities are encouraged to engage in collaborative projects at European (e.g. Euratom Research and Training Programme) and international level (e.g. IAEA and the Organisation for Economic Co-operation and Development/Nuclear Energy Agency [OECD/NEA]). International collaboration will likely intensify after the nuclear phase-out in 2022. Research activities also foster cross-cutting collaboration with the industry and regulatory bodies in order to ensure the availability of skilled professionals at all levels.

Assessment

Since the Fukushima accident in 2011, one of the policy objectives of the Energiewende has been to phase out commercial NPPs by 2022. However, the government has not decided to phase out all nuclear activities completely. D&D, waste management, nuclear non-power applications, nuclear technology dissemination and R&D are part of the remaining nuclear activities. From that basis, the nuclear industry can also in the future offer services to other countries and companies abroad.

With the enactment of the 13th Act Amending the Atomic Energy Act, a calendar to shut down all commercial NPPs by 2022 at the latest was established. Since 2011, ten reactors with a net capacity of 10 981 MW have been decommissioned in Germany. As of April 2019, seven nuclear power plants remain in operation (with a net capacity of 9 509 MW), generating around 12% of electricity needs and serving as the second-largest source of low-carbon electricity after renewables.

Seven decommissioning licences have been granted to date and eight are under evaluation. Only two reactors have still not submitted their application: Gundremmingen C and Isar 2.

The nuclear exit by 2022 will intensify Germany’s reliance on other options to meet emissions targets, such as variable renewable energy, storage, energy efficiency and the reduction of primary energy consumption. In addition, Germany also plans to phase out coal by 2038, which could reduce electricity generating capacity by 22.1 GW by 2022, or roughly 19% of total current dispatchable capacity (Appunn, 2019). With an expected increased reliance on variable renewable energy, security of electricity supply should be monitored closely in the coming years.

The “Stress Test” and the findings of the Commission to Review the Financing for the Phase-out of Nuclear Energy have revealed that, even if the provisions built up by nuclear operators in Germany were sufficient and compliant with accounting standards, the expenses associated with the storage and selection and construction of a final disposal facility could exceed estimates.

The Reorganisation Act entered into force in 2017. The federal government remains responsible for waste management activities including selection, construction and exploitation of the HGW final disposal facility, and assumed the responsibility for financing these activities. This ensures that funds will remain sufficient (without reactors generating revenues) and available when needed. Financing and operation of nuclear plant decommissioning and waste packaging remain under the responsibility of operators.

The adoption of the Site Selection Act (StandAG) in 2013 has represented major progress on waste management plans. This law sets out the criteria, decision-making principles and phases for the selection of the final location of a HGW disposal facility. Public consultation and transparency are at the core of the decision-making process, and a consultative approach has proven effective at ensuring broad consensus in other areas of the energy transition, such as the recent Coal Commission. However, a good balance between pushing the project forward and respecting stakeholders' involvement at each stage of the process will have to be found. It is anticipated that the final location of the HGW disposal facility will be decided by 2031 and commissioned by 2051.

The existing number of interim storage facilities is quite significant. On the one hand, the main advantage of a decentralised model is the reduction of nuclear waste transport needs. On the other hand, this could induce higher storage costs due to the lack of economies of scale. Given the long time frame of the final disposal project, more optimal intermediate solutions using existing sites could be explored in order to reduce overall storage costs.

Four companies will be in charge of the decommissioning of the remaining German nuclear fleet: RWE, EnBW, PreussenElektra and Kernkraftwerk Brunsbüttel. Most of them have ongoing D&D projects. RWE and PreussenElektra have already finished some decommissioning projects and have turned the sites into greenfield status, the last one in 2014. Germany has good D&D capabilities to carry out future projects cost-effectively; however, they are spread among different organisations. The mobilisation of past lessons learned, through enhanced collaboration among private and public actors, will be essential. A stable policy framework would also be desirable for supply chain optimisation.

An audit performed by BAFA in 2018 concludes that the provision schemes adopted by operators to finance decommissioning of the NPPs meet the requirements. In addition, through the introduction of the Transparency Act in 2017, the federal government has put in place effective mechanisms to verify on an annual basis that operators allocate the necessary funds for their D&D obligations. This, and the strong technical capabilities of the German nuclear industry indicated above, contributes to overall risk reduction of future D&D projects.

The deficits of waste management infrastructure can hinder D&D works. The Konrad mine (the planned central disposal for LLW and ILW) is expected to begin operation by 2027, five years after the nuclear phase-out. Operators are forced to build ad hoc additional interim storage capacities, leading to additional expenses in the D&D process that could be avoided by timely availability of the facility. Given the current separation of responsibilities in Germany, further collaboration will be needed.

Germany is well aware of the importance of maintaining competence in the nuclear field. Over the last years, 21% of the energy R&D budget has been allocated to nuclear research activities. In fact, sustaining expertise is essential for the success and cost-effectiveness of future D&D and waste management projects. However, more efforts may be needed to ensure the availability of a skilled workforce over longer-term time frames that nuclear activities require.

Recommendations

The government of Germany should:

- Build a stable policy framework supporting remaining nuclear activities (dismantling and decommissioning, waste management, nuclear technology and R&D) and promote well-informed public acceptance.
- Ensure that waste management infrastructure is available in a timely manner to support decommissioning and dismantling activities, by enhancing collaboration among the different stakeholders involved in the process.
- Evaluate alternative medium-term waste management plans in order to achieve an appropriate balance between the benefits of higher centralisation at existing facilities and reduced nuclear transport needs.
- Create a national long-term nuclear knowledge management strategy to ensure the availability of a skilled workforce at all levels (regulator, operators and vendors) to perform decommissioning and dismantling and waste management activities in a cost-effective manner.

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ANNEX A: Organisations visited

Review criteria

The Shared Goals, which were adopted by the International Energy Agency (IEA) Ministers at their 4 June 1993 meeting in Paris, provide the evaluation criteria for the in-depth reviews (IDRs) conducted by the IEA. The Shared Goals are presented in Annex C.

Review team and preparation of the report

The IEA's IDR team visited Berlin from 25-29 March 2019. The team met with government officials, energy companies, interest groups, research institutions, and other organisations and stakeholders. This report was drafted on the basis of the review team's preliminary assessment of the country's energy policy and information on subsequent policy developments from the government and private-sector sources. The members of the team were:

IEA member countries:

Mr. Jeewantha Karunarathna, Australia (team leader)

Mr. Peter Beck Nellemann, Denmark

Mr. Mehmet Bulut, Sweden

Mr. Szymon Bylinski, Poland

Ms. Helen Lam, Canada

European Commission:

Mr. Johannes Schilling

Organisation for Economic Co-operation and Development (OECD) Nuclear Energy Agency:

Mr. Antonio Vaya Soler

IEA Secretariat:

Mr. Aad van Bohemen

Mr. Paolo Frankl

Ms. Divya Reddy

The team is grateful for the co-operation and assistance of the many people it met throughout the visit in Berlin. Thanks to their kind hospitality, openness and willingness to share information, the visit was highly informative, productive and enjoyable. The team expresses particular gratitude to the Federal Ministry for Economic Affairs and Energy (BMWi) for organising the visit, especially Michael Hackethal, Stefanie Schmid-Luebbert and Sven Reutzel. The team is also sincerely grateful to the Director General for Energy Policy – Heating and Efficiency, Thorsten Herdan, and the Deputy Director General for International Affairs, Ursula Borak, for meeting with the review team in Berlin and for all their support throughout the review process.

Divya Reddy managed the review visit process and drafted the report, with the exception of the nuclear chapter, which was prepared by Antonio Vaya Soler of the Nuclear Energy Agency, and the renewables chapter, which was prepared by Paolo Frankl of the IEA. Jihyun (Selena) Lee helped with drafting of the oil chapter.

The report was prepared under the guidance of Aad van Bohemen, Head of Energy Policy and Security Division. Helpful comments and updates were provided by the review team members and IEA staff, including Yasmina Abdelilah, Carlos Fernandez Alvarez, Heymi Bahar, Francois Briens, Karolina Daszkiewicz, Jason Elliott, Peter Fraser, Timur Guel, Insa Handschuch, Ailin Huang, Peter Janoska, Pharoah Le Feuvre, Stefan Lorenczik, Armin Mayer, Gergely Molnar, Andrew Prag and Mechthild Worsdorfer.

Oskar Kvarnström, Jihyun (Selena) Lee and Seo Kyung Lim managed the data and prepared the figures. Roberta Quadrelli, Faidon Papadimoulis and Jungyu Park provided support on statistics. Therese Walsh managed the editing process, and Astrid Dumond managed the production process and Ms. Isabelle Nonain-Semelin finalised the layout. Jad Mouawad supported the press launch.

Organisation visited

During its visit in Berlin, the review team met with the following organisations:

Federal Association of the Energy and Water Industries (BDEW)
German Technical and Scientific Association for Gas and Water (DVGW)
German Petroleum Industry Association (MWV)
Renewable Energies Agency (AEE)
Agora Energiewende
German Renewable Energy Federation (BEE)
Tennet
German Association of Local Utilities (VKU)
50Hertz
Bundesnetzagentur
Bundeskartellamt
Federal Ministry of Transport and Digital Infrastructure (BMVI)
Federal Ministry of Finance (BMF)
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU)
German Industry Initiative Energy Efficiency (Deneff)
Mechanical Engineering Industry Association (VDMA)
German Energy Agency (Dena)
Federation of German Industries (BDI)
German Federal Ministry of Education and Research (BMBF)
Federal Ministry of Food and Agriculture (BMEL)
World Wildlife Fund (WWF)

ANNEX B: Energy balances and key statistical data

Unit: Mtoe

SUPPLY		1973	1990	2000	2010	2016	2017	2018p*
TOTAL PRODUCTION		**171.7**	**186.2**	**135.2**	**128.9**	**115.9**	**115.0**	**111.6**
Coal		141.4	121.7	60.6	45.9	39.7	39.4	37.6
Peat		-	0.1	0.0	-	-	-	-
Oil		6.9	4.7	3.9	3.7	3.6	3.5	3.5
Natural gas		16.4	13.5	15.8	11.1	6.6	6.0	4.7
Biofuels and waste[1]		2.5	4.8	7.9	25.0	31.3	30.9	29.9
Nuclear		3.2	39.8	44.2	36.6	22.1	19.9	19.8
Hydro		1.3	1.5	1.9	1.8	1.8	1.7	1.5
Wind		-	0.0	0.8	3.3	6.8	9.1	9.6
Geothermal		-	..	..	0.1	0.3	0.3	0.3
Solar/other		-	0.0	0.1	1.5	3.9	4.1	4.7
TOTAL NET IMPORTS[2]		**164.1**	**160.4**	**197.0**	**193.2**	**193.4**	**195.4**	**188.4**
Coal	Exports	18.3	8.1	0.5	0.9	1.4	1.5	1.5
	Imports	15.2	11.5	22.2	32.6	39.7	33.8	30.0
	Net imports	-3.1	3.4	21.7	31.6	38.3	32.3	28.5
Oil	Exports	9.8	10.1	22.0	18.6	22.8	23.4	22.3
	Imports	170.7	132.2	148.9	130.7	132.0	133.9	127.5
	Int'l marine and aviation bunkers	-7.0	-6.9	-8.6	-10.7	-11.4	-11.8	-11.8
	Net imports	153.9	115.2	118.3	101.4	97.8	98.6	93.4
Natural gas	Exports	0.1	0.9	4.2	17.2	19.3	26.9	27.4
	Imports	12.4	42.7	61.1	78.8	81.6	95.7	97.9
	Net imports	12.3	41.8	56.9	61.6	62.3	68.8	70.5
Electricity	Exports	0.7	2.6	3.6	5.0	6.8	6.9	6.9
	Imports	1.7	2.7	3.9	3.7	2.4	2.4	2.7
	Net imports	1.0	0.1	0.3	-1.3	-4.3	-4.5	-4.2
TOTAL STOCK CHANGES		**-1.1**	**4.7**	**4.3**	**4.2**	**0.8**	**0.9**	**-1.7**
TOTAL SUPPLY (TPES)[3]		**334.7**	**351.2**	**336.6**	**326.4**	**310.1**	**311.2**	**298.3**
Coal		139.4	128.6	84.8	78.9	77.2	71.4	67.1
Peat		-	-	0.0	-	-	-	-
Oil		158.7	121.4	124.8	104.7	101.4	103.0	97.9
Natural gas		28.7	55.0	71.9	75.9	70.3	75.3	71.5
Biofuels and waste[1]		2.5	4.8	7.9	24.8	30.7	31.0	30.0
Nuclear		3.2	39.8	44.2	36.6	22.1	19.9	19.8
Hydro		1.3	1.5	1.9	1.8	1.8	1.7	1.5
Wind		-	0.0	0.8	3.3	6.8	9.1	9.6
Geothermal		-	-	-	0.1	0.3	0.3	0.3
Solar/other		-	0.0	0.1	1.5	3.9	4.1	4.7
Electricity trade[4]		1.0	0.1	0.3	-1.3	-4.3	-4.5	-4.2
Shares in TPES (%)								
Coal		*41.6*	*36.6*	*25.2*	*24.2*	*24.9*	*22.9*	*22.5*
Peat		-	-	*0.0*	-	-	-	-
Oil		*47.4*	*34.6*	*37.1*	*32.1*	*32.7*	*33.1*	*32.8*
Natural gas		*8.6*	*15.7*	*21.3*	*23.3*	*22.7*	*24.2*	*24.0*
Biofuels and waste[1]		*0.7*	*1.4*	*2.3*	*7.6*	*9.9*	*10.0*	*10.1*
Nuclear		*0.9*	*11.3*	*13.1*	*11.2*	*7.1*	*6.4*	*6.6*
Hydro		*0.4*	*0.4*	*0.6*	*0.6*	*0.6*	*0.6*	*0.5*
Wind		-	-	*0.2*	*1.0*	*2.2*	*2.9*	*3.2*
Geothermal		-	-	-	*0.0*	*0.1*	*0.1*	*0.1*
Solar/other		-	*0.0*	*0.0*	*0.5*	*1.3*	*1.3*	*1.6*
Electricity trade[4]		*0.3*	-	*0.1*	*-0.4*	*-1.4*	*-1.4*	*-1.4*

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

*Data for 2018 are provisional.

Unit: Mtoe

DEMAND							
FINAL CONSUMPTION	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
TFC	**241.7**	**240.8**	**231.4**	**228.9**	**224.2**	**227.0**	**..**
Coal	55.7	39.2	9.0	7.2	7.3	7.2	..
Peat	-	-	0.0	-	-	-	..
Oil	133.3	111.2	114.1	94.7	92.2	94.1	..
Natural gas	18.6	39.1	55.1	56.4	55.0	55.4	..
Biofuels and waste[1]	1.7	3.0	4.7	13.1	14.7	15.2	..
Geothermal	-	-	-	0.1	0.1	0.1	..
Solar/other	-	0.0	0.1	0.5	0.7	0.7	..
Electricity	26.9	39.1	41.6	45.8	44.5	44.6	..
Heat	5.5	9.2	6.8	11.3	9.8	9.8	..
Shares in TFC (%)							
Coal	*23.0*	*16.3*	*3.9*	*3.1*	*3.2*	*3.2*	..
Peat	-	-	*0.0*	-	-	-	..
Oil	*55.1*	*46.2*	*49.3*	*41.4*	*41.1*	*41.5*	..
Natural gas	*7.7*	*16.2*	*23.8*	*24.6*	*24.6*	*24.4*	..
Biofuels and waste [1]	*0.7*	*1.2*	*2.0*	*5.7*	*6.5*	*6.7*	..
Geothermal	-	-	-	*0.0*	*0.0*	*0.0*	..
Solar/other	-	*0.0*	*0.0*	*0.2*	*0.3*	*0.3*	..
Electricity	*11.1*	*16.3*	*18.0*	*20.0*	*19.8*	*19.7*	..
Heat	*2.3*	*3.8*	*3.0*	*4.9*	*4.4*	*4.3*	..
TOTAL INDUSTRY[5]	**105.5**	**89.1**	**76.4**	**77.9**	**77.3**	**79.3**	**..**
Coal	29.5	21.1	7.7	6.1	6.7	6.6	..
Peat	-	-	-	-	-	-	..
Oil	46.5	26.9	27.8	23.9	20.8	22.1	..
Natural gas	12.5	19.3	21.4	22.0	22.1	22.9	..
Biofuels and waste[1]	0.0	0.8	0.5	3.1	3.9	3.9	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	-	-	..
Electricity	15.3	18.6	18.2	19.3	19.5	19.6	..
Heat	1.6	2.4	0.9	3.5	4.3	4.1	..
Shares in total industry (%)							
Coal	*28.0*	*23.7*	*10.0*	*7.8*	*8.7*	*8.4*	..
Peat	-	-	-	-	-	-	..
Oil	*44.1*	*30.2*	*36.4*	*30.7*	*26.9*	*27.9*	..
Natural gas	*11.9*	*21.7*	*28.0*	*28.3*	*28.6*	*28.9*	..
Biofuels and waste [1]	-	*0.9*	*0.6*	*4.0*	*5.1*	*4.9*	..
Geothermal	-	-	-	-	-	-	..
Solar/other	-	-	-	-	-	-	..
Electricity	*14.5*	*20.9*	*23.8*	*24.8*	*25.2*	*24.7*	..
Heat	*1.5*	*2.7*	*1.2*	*4.5*	*5.5*	*5.2*	..
TRANSPORT[3]	**36.1**	**54.5**	**59.5**	**53.2**	**56.8**	**57.7**	**..**
OTHER[6]	**100.1**	**97.2**	**95.5**	**97.9**	**90.0**	**89.9**	**..**
Coal	24.5	18.2	1.3	1.1	0.5	0.5	..
Peat	-	-	0.0	-	-	-	..
Oil	53.2	31.0	28.4	22.1	18.6	18.4	..
Natural gas	6.1	19.8	33.7	33.9	32.5	32.0	..
Biofuels and waste[1]	1.7	2.2	4.0	7.1	8.2	8.7	..
Geothermal	-	-	-	0.1	0.1	0.1	..
Solar/other	-	0.0	0.1	0.5	0.7	0.7	..
Electricity	10.7	19.3	22.0	25.4	24.0	24.0	..
Heat	3.9	6.7	5.9	7.8	5.5	5.7	..
Shares in other (%)							
Coal	*24.4*	*18.7*	*1.4*	*1.1*	*0.6*	*0.6*	..
Peat	-	-	*0.0*	-	-	-	..
Oil	*53.2*	*31.9*	*29.8*	*22.6*	*20.6*	*20.4*	..
Natural gas	*6.1*	*20.3*	*35.3*	*34.6*	*36.1*	*35.5*	..
Biofuels and waste [1]	*1.7*	*2.2*	*4.2*	*7.3*	*9.1*	*9.6*	..
Geothermal	-	-	-	*0.1*	*0.1*	*0.1*	..
Solar/other	-	*0.0*	*0.1*	*0.5*	*0.7*	*0.8*	..
Electricity	*10.7*	*19.9*	*23.0*	*26.0*	*26.7*	*26.7*	..
Heat	*3.9*	*6.9*	*6.2*	*7.9*	*6.1*	*6.3*	..

Unit: Mtoe

DEMAND							
ENERGY TRANSFORMATION AND LOSSES	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p***
ELECTRICITY GENERATION[7]							
Input (Mtoe)	98.5	138.0	132.9	139.5	129.4	125.3	..
Output (Mtoe)	32.2	47.1	49.2	53.9	55.3	55.7	55.4
Output (TWh)	374.4	547.7	572.3	626.6	643.5	647.7	643.7
Output shares (%)							
Coal	*69.0*	*58.7*	*53.1*	*43.6*	*42.5*	*39.0*	*37.5*
Peat	-	-	-	-	-	-	-
Oil	*12.0*	*1.9*	*0.8*	*1.4*	*0.9*	*0.9*	*0.8*
Natural gas	*10.9*	*7.4*	*9.2*	*14.4*	*12.8*	*13.5*	*13.2*
Biofuels and waste [1]	*0.8*	*0.9*	*1.8*	*6.5*	*9.1*	*9.0*	*9.1*
Nuclear	*3.2*	*27.8*	*29.6*	*22.4*	*13.2*	*11.8*	*11.8*
Hydro	*4.1*	*3.2*	*3.8*	*3.3*	*3.2*	*3.1*	*2.8*
Wind	-	-	*1.6*	*6.0*	*12.2*	*16.3*	*17.3*
Geothermal	-	-	-	-	-	-	-
Solar/other	-	-	-	*2.2*	*6.2*	*6.3*	*7.4*
TOTAL LOSSES	**92.5**	**110.2**	**103.1**	**97.7**	**87.1**	**82.8**	**..**
of which:							
Electricity and heat generation[8]	59.9	80.2	76.1	73.3	62.8	58.4	..
Other transformation	8.7	9.4	8.1	7.6	7.5	7.6	..
Own use and transmission/distribution losses	23.9	20.6	18.9	16.8	16.7	16.8	..
Statistical differences	**0.5**	**0.2**	**2.1**	**-0.3**	**-1.1**	**1.5**	**..**
INDICATORS	**1973**	**1990**	**2000**	**2010**	**2016**	**2017**	**2018p**
GDP (billion 2010 USD)	1 729.0	2 568.6	3 123.9	3 417.1	3 801.9	3 883.9	3 939.2
Population (millions)	79.0	79.4	81.5	80.3	82.3	82.7	82.9
TPES/GDP (toe/1000 USD)[9]	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Energy production/TPES	0.5	0.5	0.4	0.4	0.4	0.4	0.4
Per capita TPES (toe/capita)	4.2	4.4	4.1	4.1	3.8	3.8	3.6
Oil supply/GDP (toe/1000 USD)[9]	0.1	0.0	0.0	0.0	0.0	0.0	0.0
TFC/GDP (toe/1000 USD)[9]	0.1	0.1	0.1	0.1	0.1	0.1	..
Per capita TFC (toe/capita)	3.1	3.0	2.8	2.9	2.7	2.7	..
CO_2 emissions from fuel combustion ($MtCO_2$)[10]	1 052.2	940.0	812.3	758.8	734.5	718.8	0.0
CO_2 emissions from bunkers ($MtCO_2$)[10]	21.7	21.3	26.3	32.7	34.8	35.9	0.0
GROWTH RATES (% per year)	**73-90**	**90-00**	**00-10**	**10-15**	**15-16**	**16-17**	**17-18**
TPES	0.3	-0.4	-0.3	-1.1	0.6	0.4	-4.2
Coal	-0.5	-4.1	-0.7	0.1	-2.7	-7.5	-6.0
Peat	-	-	-100.0	-	-	-	-
Oil	-1.6	0.3	-1.7	-0.7	0.2	1.5	-4.9
Natural gas	3.9	2.7	0.6	-3.0	7.9	7.1	-5.1
Biofuels and waste[1]	3.9	5.1	12.2	3.8	2.5	1.1	-3.2
Nuclear	16.1	1.0	-1.9	-8.2	-7.8	-9.8	-0.4
Hydro	0.8	2.2	-0.4	-2.0	8.3	-1.9	-10.7
Wind	-	63.2	15.0	15.9	-0.8	34.5	5.6
Geothermal	-	-	-	20.0	25.7	-4.8	-
Solar/other	-	30.3	29.4	21.9	-1.4	2.9	16.5
TFC	-0.0	-0.4	-0.1	-0.8	1.8	1.2	..
Electricity consumption	2.2	0.6	1.0	-0.7	0.5	0.3	..
Energy production	0.5	-3.1	-0.5	-1.4	-3.3	-0.8	-2.9
Net oil imports	-1.7	0.3	-1.5	-0.7	-0.0	0.9	-5.3
GDP	2.4	2.0	0.9	1.7	2.2	2.2	1.4
TPES/GDP	-2.0	-2.4	-1.2	-2.8	-1.6	-1.8	-5.5
TFC/GDP	-2.3	-2.3	-1.0	-2.4	-0.3	-1.0	..

0 is negligible, - is nil, .. is not available, x is not applicable. Please note: rounding may cause totals to differ from the sum of the elements.

*Data for 2018 are provisional.

Footnotes to energy balances and key statistical data

1. Biofuels and waste comprises solid biofuels, liquid biofuels, biogases, industrial waste and municipal waste. Data are often based on partial surveys and may not be comparable between countries.
2. In addition to coal, oil, natural gas and electricity, total net imports also include biofuels.
3. Excludes international marine bunkers and international aviation bunkers.
4. Total supply of electricity represents net trade. A negative number in the share of TPES indicates that exports are greater than imports.
5. Industry includes non-energy use.
6. Other includes residential, commercial and public services, agriculture/forestry, fishing, and other non-specified.
7. Inputs to electricity generation include inputs to electricity, CHP and heat plants. Output refers only to electricity generation.
8. Losses arising in the production of electricity and heat at main activity producer utilities and autoproducers. For non-fossil-fuel electricity generation, theoretical losses are shown based on plant efficiencies of approximately 33% for nuclear, 10% for geothermal and 100% for hydro, wind and solar photovoltaic.
9. Toe per thousand US dollars at 2010 prices and exchange rates.
10. "CO_2 emissions from fuel combustion" have been estimated using the Intergovernmental Panel on Climate Change (IPCC) Tier I Sectoral Approach methodology from the 2006 IPCC Guidelines. Emissions from international marine and aviation bunkers are not included in national totals.

ANNEX C: International Energy Agency "Shared Goals"

The member countries* of the International Energy Agency (IEA) seek to create conditions in which the energy sectors of their economies can make the fullest possible contribution to sustainable economic development and to the well-being of their people and of the environment. In formulating energy policies, the establishment of free and open markets is a fundamental point of departure, though energy security and environmental protection need to be given particular emphasis by governments. IEA countries recognise the significance of increasing global interdependence in energy. They therefore seek to promote the effective operation of international energy markets and encourage dialogue with all participants. In order to secure their objectives, member countries therefore aim to create a policy framework consistent with the following goals:

1. Diversity, efficiency and flexibility within the energy sector are basic conditions for longer-term energy security: the fuels used within and across sectors and the sources of those fuels should be as diverse as practicable. Non-fossil fuels, particularly nuclear and hydropower, make a substantial contribution to the energy supply diversity of IEA countries as a group.

2. Energy systems should have **the ability to respond promptly and flexibly to energy emergencies.** In some cases, this requires collective mechanisms and action: IEA countries co-operate through the Agency in responding jointly to oil supply emergencies.

3. The environmentally sustainable provision and use of energy are central to the achievement of these shared goals. Decision makers should seek to minimise the adverse environmental impacts of energy activities, just as environmental decisions should take account of the energy consequences. Government interventions should respect the Polluter Pays Principle where practicable.

4. More environmentally acceptable energy sources need to be encouraged and developed. Clean and efficient use of fossil fuels is essential. The development of economic non-fossil sources is also a priority. A number of IEA member countries wish to retain and improve the nuclear option for the future, at the highest available safety standards, because nuclear energy does not emit carbon dioxide. Renewable sources will also have an increasingly important contribution to make.

5. Improved energy efficiency can promote both environmental protection and energy security in a cost-effective manner. There are significant opportunities for greater energy efficiency at all stages of the energy cycle from production to consumption. Strong efforts by governments and all energy users are needed to realise these opportunities.

6. Continued **research, development and market deployment of new and improved energy technologies** make a critical contribution to achieving the objectives outlined above. Energy technology policies should complement broader energy policies. International co-operation in the development and dissemination of energy technologies, including industry participation and co-operation with non-member countries, should be encouraged.

7. Undistorted energy prices enable markets to work efficiently. Energy prices should not be held artificially below the costs of supply to promote social or industrial goals. To the extent necessary and practicable, the environmental costs of energy production and use should be reflected in prices.

8. Free and open trade and a secure framework for investment contribute to efficient energy markets and energy security. Distortions to energy trade and investment should be avoided.

9. Co-operation among all energy market participants helps to improve information and understanding, and encourages the development of efficient, environmentally acceptable and flexible energy systems and markets worldwide. These are needed to help promote the investment, trade and confidence necessary to achieve global energy security and environmental objectives.

(The Shared Goals were adopted by IEA Ministers at the meeting of 4 June 1993, Paris, France.)

* Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom, the United States.

ANNEX D: Glossary and list of abbreviations

Organisations

AGEB	Arbeitsgemeinschaft Energiebilanzen (Working Group on Energy Balances)
AGEE-Stat	Arbeitsgruppe Erneuerbare Energien-Statistik (Working Group on Renewable Energies Statistics)
APEE	*Anreizprogramm* Energieeffizienz (Energy Efficiency Incentive Program)
BAFA	*Bundesamt* für Wirtschaft und Ausfuhrkontrolle (Federal Office for Economic Affairs and Export Control)
BaFin	Bundesanstalt für Finanzdienstleistungsaufsicht (Federal Financial Supervisory Authority)
BBK	*Bundesamts für Bevölkerungsschutz* und Katastrophenhilfe (Federal Office of Civil Protection and Disaster Assistance)
BDH	Bundesverband der deutschen heizungsindustrie (Federal Association of the Germany Heating Industry)
BEA	Berliner Energieagentur (Berlin Energy Agency)
BfE	*Bundesamt* für *kerntechnische* Entsorgungssicherheit (Federal Office for the Safety of Nuclear Waste Management)
BfEE	Bundesstelle für Energieeffizienz (Federal Bureau for Energy Efficiency)
BfS	*Bundesamt* für Strahlenschutz (Federal Office for Radiation Protection)
BGE	Bundesgesellschaft für Endlagerung mbH (Federal Company for Final Disposal)
BGR	Bundesanstalt für Geowissenschaften und Rohstoffe (Federal Institute for Geosciences and Natural Resources)
BGZ	Gesellschaft für Zwischenlagerung mbH (Company for Interim Storage)
BImSchG	Bundes-Immissionsschutzgesetz (Federal Immission Control Act)
Biokraft-NachV	Biokraftstoff-Nachhaltigkeitsverordnung (Biofuel Sustainability Regulation)
BMBF	Bundesministerium für Bildung und Forschung (Federal Ministry of Education and Research)
BMEL	Bundesministerium für Ernährung und Landwirtschaft (Federal Ministry of Food and Agriculture)
BMF	*Bundesministerium* der Finanzen (Federal Ministry of Finance)
BMI	Bundesministeriums des Innern, für Bau und Heimat (Federal Ministry of the Interior, Building and Community)
BMU	Bundesministeriums für Umwelt, Naturschutz und nukleare Sicherheit (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety)
BMVI	*Bundesministerium* für Verkehr und digitale Infrastruktur (Federal Ministry of Transport and Digital Infrastructure)

BMWi	Bundesministeriums für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy)
BSI	Bundesamt für Sicherheit in der Informationstechnik (Federal Office for Information Security)
CarEnVKV	Car Energieverbrauchskennzeichnungsverordnung (Ordinance on Energy Consumption Labelling for Passenger Cars)
DAS	Deutsche Anpassungsstrategie (German Climate Change Adaptation Strategy)
DBE	Deutsche Gesellschaft zum Bau und Betrieb von Endlagern für Abfallstoffe mbH (German Society for the Construction and Operation of Waste Repositories)
DEHSt	Deutsche Emissionshandelsstelle (German Emissions Trading Authority)
Dena	Deutsche Energie-Agentur (German Energy Agency)
DLR	Deutsches Zentrum für Luft- und Raumfahrt *(German Aerospace Center)*
EBV	Erdölbevorratungsverband (Petroleum Stocksupply Association)
EEG	Erneuerbare Energien Gesetz (Renewable Energy Act)
EEWärmeG	Erneuerbare-Energien-Wärmegesetz (Renewable Energies Heat Act)
EKF	Energie- und *Klimafonds (*Energy and Climate Fund)
EnEG	Energieeinsparungsgesetz (Energy Conservation Act)
EnEV	Energieeinsparverordnung (Energy Saving Ordinance)
EnLAG	Energieleitungsausbaugesetz (Power Grid Expansion Act)
EnWG	Energiewirtschaftsgesetz (Energy Industry Act)
ESK	Entsorgungskommission (Nuclear Waste Management Commission)
EWN	Entsorgungswerk für Nuklearanlagen GmbH (Disposal Plant for Nuclear Plants)
GNS	Gesellschaft für Nuklear-Service (Society for Nuclear Service)
GRS	Gesellschaft für Anlagen- und Reaktorsicherheit (Society for Plant and Reactor Safety)
HGF	*Helmholtz-Gemeinschaft* Deutscher Forschungszentren (Helmholtz Association of German Research Centres)
KENFO	Entsorgungsfonds (Nuclear Waste Disposal Fund)
KGV	Supply Co-ordination Group
KliVO	Klimavorsorge-Portal (German Climate Preparedness Portal)
KraftStG	Kraftfahrzeugsteuergesetz (Motor Vehicle Tax Act)
KTA	Kerntechnische Ausschuss (Nuclear Safety Standards Commission)
KVR	Krisenversorgungsrat (Crisis Supply Council)
LAA	*Länderausschuss* für Atomkernenergie (Länder Committee for Nuclear Energy)
MAP	Marktanreizprogramm (Market Incentive Programme)

MaStR	*Marktstammdatenregister (Market Data Register*)
NABEG 2.0	Netzausbaubeschleunigungsgesetzes (Grid Expansion Acceleration Act)
NetzResV	Netzreserveverordnung (Regulation on Network Reserve)
NPE	Nationale Plattform Elektromobilität (National Platform on Electric Mobility)
NPM	Nationale Plattform Zukunft der Mobilität (National Platform Future of Mobility)
NWO	Nord-West Oelleitung (North-West Oil Line)
RMR	Rhein-Main-Rohrleitungstransportgesellschaft (Rhine-Main Pipeline Transport Company)
RSK	*Reaktor*-Sicherheitskommission (Reactor Safety Commission)
SINTEG	Schaufenster für intelligente Energie: Forschung für das Stromnetz der Zukunft (Smart Energy Showcases – Digital Agenda for the Energy Transition)
SMARD	Strommarktdaten (Electricity Market Data)
SSK	Strahlenschutzkommission (Commission on Radiological Protection)
StandAG	Standortauswahlgesetz (Site Selection Act)
StBA	Statistisches Bundesamt (Federal Statistical Office)
TÜV	Technischer Überwachungsverein (Technical Inspection Association)
UBA	Umweltbundesamt (Federal Environment Agency)
VDA	Verband der Automobilindustrie (Association of the Automobile Industry)

Abbreviations and acronyms

AC	alternating current
ACT	Accelerating CCS Technologies
BRP	balance responsible party
BWR	boiling water reactor
CCUS	carbon capture, utilisation and storage
CEM	Clean Energy Ministerial
CNG	compressed natural gas
CO_2	carbon dioxide
CPQ	climate protection quota
D&D	decontamination and decommissioning
DSO	distribution system operator
E&P	exploration and production
EEX	European Energy Exchange
ENSREG	European Nuclear Safety Regulators Groups
ENTSO-E	European Network of Transmission System Operators for Electricity

EPC	energy performance contract
EPEX SPOT	European Power Exchange
ESD	Effort Sharing Decision
ESR	Effort Sharing Regulation
ETS	emissions trading system
EU	European Union
EUGAL	European Gas Pipeline Link
EV	electric vehicle
FiT	feed-in tariff
GCC	Grid Control Co-operation
GDP	gross domestic product
GHG	greenhouse gas
H-gas	high-calorific gas
HGW	heat-generating waste
HLW	high-level radioactive waste
HVDC	high-voltage, direct current
IAEA	International Atomic Energy Agency
IDR	in-depth review
IEA	International Energy Agency
IEA 30	30 member of the International Energy Agency
IEP	International Energy Program
IGCC	International Grid Control Co-operation
ILW	intermediate-level radioactive waste
L-gas	low-calorific natural gas
LCP BREF	Best Available Technologies for Large Combustion Plants
LLW	low-level waste
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULUCF	land use, land-use change and forestry
MAM	market area manager
MI	Mission Innovation
MTBE	methyl tert-butyl ether
MTU Fuels	Market Transparency Unit for Fuels
MVL	Mineralölverbundleitung
NAPE	National Action Plan on Energy Efficiency
NATO	North Atlantic Treaty Organization

NDP	network development plan
NEA	Nuclear Energy Agency
NECP	National Energy and Climate Plan
NESO	National Emergency Strategy Organisation
NGC	NetConnect Germany
NGL	natural gas liquids
NHGW	negligible heat-generating waste
NPP	nuclear power plant
NREAP	National Renewable Energy Action Plan
OECD	Organisation for Economic Co-operation and Development
p.a.	per annum
PCI	Projects of Common Interest
PHEV	plug-in hybrid
PPP	purchasing power parity
PV	photovoltaic
PWR	pressurised water reactor
R&D	research and development
RD&D	research, development and demonstration
RES	renewable energy sources
RRP	Rotterdam Rhine Pipeline
S&T	Agreements on Scientific and Technological Co-operation
SBP	specific boiling point
SET	Strategic Energy Technology
SME	small and medium-sized enterprise
SNF	spent nuclear fuel
SPF	seasonal performance factor
TAL	Transalpine Pipeline
TCP	Technology Collaboration Programme
TFC	total final consumption
TPES	total primary energy supply
TSO	transmission system operator
TTF	Title Transfer Facility
WKGT	Warth & Klein Grant Thornton

Units of measure

b/d	barrels per day
bcm	billion cubic metres
c/kWh	cents per kilowatt-hour
c/L	cents per litre
gCO_2/km	grammes of carbon dioxide per kilometre
gCO_2/kWh	grammes of carbon dioxide per kWh
GW	gigawatts
GWh	gigawatt-hours
kb/d	thousand barrels per day
kg	kilogrammes
$kgCO_2$/USD	kilogrammes of carbon dioxide per United States dollar
km	kilometres
kW	kilowatts
kWh	kilowatt-hours
L	litres
L/100 km	litres per 100 kilometres
m^3	cubic metres
mb	million barrels
mcm	million cubic metres
mg/kg	milligrammes per kilogramme
mg/m^3	milligrammes per cubic metre
Mt	million tonnes
$MtCO_2$	million tonnes of carbon dioxide
$MtCO_2$-eq	million tonnes of carbon dioxide equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatts
MWh	megawatt-hours
tCO_2	tonnes of carbon dioxide
TJ	terajoule
toe	tonnes of oil equivalent
toe/cap	tonnes of oil equivalent per capita
TWh	terawatt-hours
vkm	vehicle kilometre

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Energy Policy Review

The International Energy Agency (IEA) regularly conducts in-depth peer reviews of the energy policies of its member countries. This process supports energy policy development and encourages the exchange of international best practices and experiences. The “Energiewende” continues to be the defining feature of Germany’s energy policy landscape. In place for nearly a decade, the Energiewende is a major plan for transforming the country’s energy system to make it more efficient and supplied mainly by renewable sources. The Energiewende is clearly visible in electricity generation, where it has increased the share of renewables. Yet despite progress on lowering overall emissions, Germany is struggling to meet its near-term emissions reduction targets, in large part because of uneven progress across sectors. It faces notable challenges in transport and heating. Now, the government must refocus its efforts to achieve stronger emissions reductions in lagging sectors. A recently adopted climate action plan, which includes a carbon price in the transport and heating sectors, represents an important step in the right direction. In its energy transition so far, Germany has maintained a high degree of oil, natural gas and electricity supply security. Planned nuclear and coal phase-outs are set to increase the country’s reliance on natural gas, making it increasingly important to continue efforts to diversify gas supply options, including through liquefied natural gas imports. In this report, the IEA provides energy policy recommendations to help Germany smoothly manage the transformation of its energy sector.