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1 Executive summary

Background

This report is the Seventh National Communication by the Federal Republic of Germany to the Conference of the Parties to the UN Framework Convention on Climate Change pursuant to Article 12 of the Convention, describing the country's climate action. In this way, the German government informs the Conference of the Parties about progress in implementing climate change mitigation measures in the Federal Republic of Germany every four years. Germany's Seventh National Communication on Climate Change was prepared on the basis of the UNFCCC guidelines for the preparation of national communications, taking into account the review report on the Sixth National Communication of December 2013. It should be viewed in continuity with its predecessors from 1994-2014.

This report presents German climate policies against the backdrop of legislative, political and socio-economic conditions, explores the effects of climate change and describes policies and measures that have been initiated to reduce greenhouse gas emissions and adapt to climate change. It also describes previous and projected effects of those measures. Finally, it reports on financial support, technology transfer, and activities in the field of education, training and public awareness. The data on which this report is based are for 2014 to 2017, depending on availability. The structure and content of the report are in accordance with the UNFCCC Guidelines on reporting and review;¹ additional content from the revised Guidelines for the preparation of national communications,² which have not yet entered into force, has also been included.

Germany is also submitting a Biennial Report at the same time as this National Communication. The format of biennial reporting was approved at the 17th session of the Conference of the Parties in Durban in 2011. Every four years, the deadline for submission of the Biennial Report coincides with submission of the National Communication for the group of industrialised countries (Annex I parties), which includes Germany. The basis for biennial reporting by the industrialised countries is table formats that were approved at the 18th session of the Conference of the Parties in Doha.

The third German Biennial Report is being published as an annex to this National Communication.

Current status of German climate policy

Climate policies in Germany have continued to develop dynamically since publication of the Sixth National Communication in January 2014.

- Germany's total greenhouse gas emissions were almost 28 % lower in 2015 than in 1990 (2017 National Inventory Report).
- The EU target for 2020 is to achieve a 20 % reduction in greenhouse gas emissions compared with 1990 levels. The plan is to meet the target by a combination of the EU Emissions Trading Scheme and binding national targets by the Member States. EU emissions trading uses quantity limits to cap emissions by selected industries and production processes throughout the EU. The reduction commitments in the other sectors are distributed among the Member States. As part of effort sharing

¹ UNFCCC Guidelines on reporting and review (...), document FCCC/CP/1999/7.

² Revision of the Guidelines for the preparation of national communications (...), document FCCC/SBI/2016/L.22.

within the EU,³ Germany has undertaken to reduce emissions in the sectors not regulated by the ETS by 14 % from 2005 levels by 2020. Germany is well on its way to making its contribution for the 2013-2020 period.

- As previously reported, by achieving a total average reduction of 23.6 %, ⁴ Germany has more than fulfilled its target for the first commitment period of the Kyoto Protocol – as part of the overall EU target – of a total average reduction of 21 % between 2008 and 2012.
- The German government has also intensified its climate finance activities, further increasing its financial support for emerging economies and developing countries up to 2016 to promote climate change mitigation and adaptation. The German government aims to double its international climate financing by 2020, based on 2014.
- In its Climate Action Plan 2050, the German government also confirmed and further defined its ambitious national climate targets: Germany intends to be largely greenhouse gas neutral by 2050. The German government also affirms the intermediate targets of reducing its greenhouse gas emissions by at least 55 % by 2030 and 70 % by 2040 compared with base year 1990. In addition, the Climate Action Plan 2050 spells out the government's 2030 climate target for the individual sectors, describes the development pathways needed in those sectors, lists initial implementation measures and sets up a process for monitoring and refining the policies and measures. This is the means by which Germany will play its part in achieving the Paris Agreement's aim to limit global warming to well below 2 degrees Celsius and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius.
- The German government adopted the Climate Action Programme 2020 in December 2014. It did so in response to the 2013 Projections Report, which stated that the national emission reduction target of minus 40 % by 2020 would probably not be achieved with the measures that had been put in place at that time. In order to reach the 40 % target, therefore, additional efforts needed to be made. The German government did this with the most comprehensive action programme up to that time, which contained measures in all sectors.
- Continuing efforts to pursue the energy transition in Germany are also making an important contribution towards implementing the Climate Action Programme 2020 and the Climate Action Plan 2050.

Overall, climate action measures and the energy transition have resulted in considerable progress in achieving the target for 2020. However, current projections indicate that they are not sufficient to achieve Germany's ambitious climate action targets for 2020. According to the latest estimates (2017 Projections Report)⁵, which the German government does not fully endorse but which it will take into account in its future considerations, measures that have been approved so far – including those in the Climate Action Programme 2020 – will be able to reduce greenhouse gases by between 35 and 38 % by 2020. The question of

³ Effort Sharing Decision.

⁴ Report on the individual review of the report upon expiration of the additional period for fulfilling commitments (true-up period) for the first commitment period of the Kyoto Protocol of Germany (document FCCC/KP/CMP/2016/TPR/DEU).

⁵ Projections report 2017. German version available online at http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/envwqc4_g/170426_PB_2017_-_final.pdf; English version will be available in due course at <http://acm.eionet.europa.eu/>.

whether further measures should be taken – and if so which ones – in order to achieve the target of reducing greenhouse gas emissions by at least 40 % by 2020 is being considered. The German government can, if necessary, use the first programme of measures for the Climate Action Plan 2050 in 2018 to make appropriate additions to the existing package of measures.

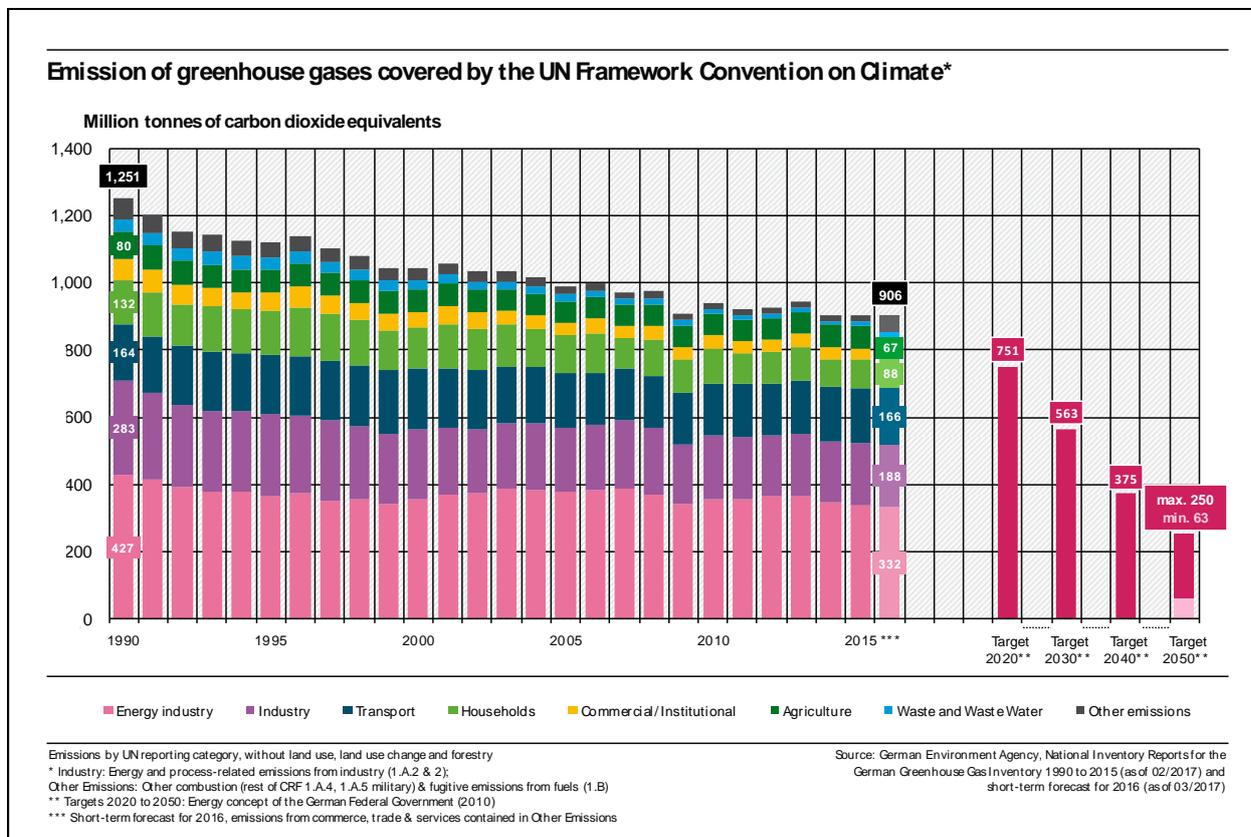


Figure 1: Trends in greenhouse gas emissions since 1990 by category⁶

Germany is relying on a mix of measures and instruments to achieve its climate policy targets. The regulatory framework is defined by primary and secondary legislation, and financial incentives are among the tools used to influence stakeholder behaviour. Other economic instruments, such as the European Emissions Trading Scheme, use a pricing signal to influence the actions of the relevant players. Other programmes also play their part in supporting technological research, the use of renewable energy, and measures that will eliminate impediments to climate action and ensure it is accepted, and improve energy efficiency by providing advisory services and information and facilitating networking and public participation. Adaptation measures play an important role, as well. Germany will also fulfil its international responsibilities through financial support and technology transfer.

1.1 National circumstances

This report describes national circumstances that are relevant to climate action for the following areas: legislation, population trend, economic development, geography, climate and climate change, energy, transport, industry, the trade, commerce and services sector, waste/wastewater, buildings, agriculture and forestry.

⁶ Federal Environment Agency (2017c).

Environmental protection in the constitution

Protection of the natural resources that sustain life has been enshrined as a national objective in the Basic Law – the Federal Republic of Germany's constitution – since 1994. Germany is a federal republic in which legislative authority is divided between the federal government and the states (“Länder”) under the Basic Law. The individual areas of environmental law are subject to concurrent legislation. This means that the Länder have the power to legislate as long as the federal government does not exercise its legislative authority. However, it is the federal government that is able to have the decisive influence on environmental legislation and to transpose EU directives related to the environment.

Population and land use

There were 82 million people living in Germany in 2015. Its population increased between 2011 and 2015 due to particularly high net immigration. However, the causes of the decline in population persist. It is estimated that Germany's population will be between 68 and 73 million in 2060. A recently updated forecast variant that reflects the patterns of heavy migration in 2014 and 2015 puts it at 76.5 million.

Where land use is concerned, there has been another decrease in agriculture and a considerable increase in land used for settlement and transport purposes. On average, over 66 hectares were converted for use for settlement and transport purposes each day during the 2012-2015 period. In contrast, there has been little change in areas under forest. The increase in land used for settlement and transport is associated with an increase in emissions that are relevant to climate and in pollution levels.

Climate trends

According to data from Deutscher Wetterdienst (Germany's National Meteorological Service, DWD), the following general trends should be noted.

The areal mean of Germany's air temperature rose by about 1.4 degrees Celsius between 1881 and 2015. At a mean temperature of 9.9 degrees Celsius, 2015, along with 2000 and 2007, was the second-hottest year ever recorded in Germany. The following changes in precipitation have been observed in Germany: the areal mean annual precipitation has increased by about 10 % since the late 19th century (1881). There are geographic and seasonal differences in precipitation trends within Germany. For example, the increase in annual precipitation is mostly limited to western Germany, while the increase during the winter half-year in eastern Germany is mostly offset by decreases in summer. No significant trend has been observed for wind speed.

Economic development

Gross domestic product (in real terms) increased by 1.9 % in 2016, the seventh year in succession.⁷ Consolidation in the national budget continues, and the number of people in employment reached a new high in June 2017. The number of people employed in the field of environmental protection also increased. German companies continue to profit from strong international growth in “green” markets, which is estimated to be about 6.5 % from 2013 to 2025.⁸

The following table shows which Greenhouse Gas Inventory source categories (CRF categories) have been assigned to which sectors in the 2017 Projections Report. In

⁷ Federal Statistical Office (2017a).

⁸ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014a).

addition, the corresponding classification used in the German government's Climate Action Plan 2050 is also shown to enable comparison.

CRF category	2017 Projections Report	Climate Action Plan 2050	
1.A.1 Energy industries	Energy industry	Energy sector	
1.A.2 Manufacturing industries and construction	Industry	Industry	
1.A.3.a Civil aviation	Transport	Transport	
1.A.3.b Road transportation	Transport	Transport	
1.A.3.c Railways	Transport	Transport	
Navigation	Transport	Transport	
Other transportation	Transport	Energy sector	Natural gas compressor stations
1.A.4.a Commercial/institutional	Trade, commerce and services	Buildings	
1.A.4.b Residential	Households	Buildings	
1.A.4.c Agriculture/forestry/fishing (energy-related)	Trade, commerce and services	Agriculture	Including use of fuel in agriculture and forestry
1.A.5 Other (not elsewhere specified)	Trade, commerce and services	Buildings	Military (stationary and mobile)
1.B Fugitive emissions	Fugitive emissions	Energy sector	
Industrial processes	Industrial processes	Industry	
Agriculture	Agriculture	Agriculture	
LULUCF	LULUCF	-	
5 Waste and wastewater	Waste management	Other	

Table 1: Assignment of CRF categories in the 2017 Projections Report and in the 2050 Climate Action Plan⁹

⁹ 2017 Projections Report, supplied by: Öko-Institut; German version available at http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/envwqc4_g/170426_PB_2017_-_final.pdf; English version will be available in due course at <http://acm.eionet.europa.eu/>

Energy sector

Primary energy consumption in Germany has decreased slightly since 1990; it increased slightly in 2016 from both 2014 and 2015. The long-term downward trend is attributable to the determination of primary energy consumption using the physical energy content method, but improvements in efficiency are also responsible for it. Increased primary energy consumption during the 2014-2016 period is explained by the positive economic situation, an increase in population, and cool weather. There has been only a slight decrease in final energy consumption since the 1990s because economic growth and increased consumer spending are offsetting gains in efficiency. The sectoral structure of final energy consumption has changed: industry's share in total final energy consumption decreased from 31.4 % in 1990 to 29.0 % in 2015. The trade, commerce and services sector experienced a similar trend, falling slightly from 18.3 % to 15.7 %. The share accounted for by private households remained practically unchanged, while there was an increase from 25.1 % to 29.5 % in the transport sector.

A total of 34 % of primary energy consumption was met by oil in 2016, so it is still the most important fuel, followed by natural gas, whose share rose to almost 23 %. Renewables are in third place, with a share of 12.6 % – ahead of coal at 12.2 % and lignite at 11.4 %. Nuclear power's share fell to less than 7 % in 2016. Renewables' share in gross electricity generation rose to 29 % in 2016, while the share of lignite, coal and nuclear power fell to 53 %. Natural gas has seen its share double since 1990. Onshore wind energy contributed the most to renewable electricity generation in 2016, at 34.5 %, followed by biomass with a 27.4 % share (as at: 2016). The price of electricity is higher in Germany than in other countries in Europe and the rest of the world, although Germany is in the midrange among EU Member States for the prices paid by particularly energy-intensive companies due to various types of relief that are offered.

The phase-out of nuclear power cannot be considered a decisive factor in closing the remaining mitigation gap. In contrast, the electricity export balance – along with the economic cycle and lower contributions to reductions in the transport and agriculture sectors – will have a major influence on meeting Germany's climate target.

Germany's electricity export balance has been rising for years, reaching 52 terawatt hours (TWh) in 2015.¹⁰ Its lignite-fired power plants generated some 155 TWh gross in 2015.¹¹ The declining share of nuclear energy in the German electricity mix is therefore not causing the mitigation gap. The upcoming socially balanced structural changes in the lignite mining regions can make an important contribution to closing it.

Transport sector

Transport has continued to increase in Germany since 1991. Passenger transport increased 34.8 % between 1991 and 2015, with private motor transport remaining in the dominant position. Aviation, at around 171.2 %, grew faster than any other type of passenger transport if international aviation originating in Germany is included. Passenger transport by rail also rose by 60.1 %, giving it a 7.7 % share in 2015. Freight transport rose sharply, by 62.5 % between 1990 and 2015, while airfreight transport tripled. Transport of freight by road increased by 86.6 %, while the share of rail and inland waterways in total freight transport continued to decline.

¹⁰ AGEB: Gross electricity generation by type of fuel (1990-2016 (as at: February 2017)).

¹¹ AGEB: Gross electricity generation by type of fuel (1990-2016 (as at: February 2017)).

After a temporary decrease between 1999 and 2009, greenhouse gas emissions from road transport increased continuously and are now nearly at 1991 levels. The causes of the temporary downward trend in emissions were a decrease in specific fuel consumption and increasing use of biofuels as the growth rate of transport volumes slowed. The decrease was temporarily amplified by the 2008 economic crisis, when freight transport by road collapsed. Emissions rose again slightly after 2009, in spite of increases in efficiency, as more freight began to be transported by road.

Overall, greenhouse gas emissions by transport (not including international aviation and maritime shipping) were 4 % lower in 2015 than in 1991.

Buildings sector

Greenhouse gas emissions in the buildings sector decreased by about 18 % between 2008 and 2015. Most of them are caused by space heating, followed by lighting, hot water and air conditioning, whose share is small but growing. The final energy consumption – and thus greenhouse gas emissions – of a building is highly dependent on weather conditions, but energy efficiency measures and a growing share of renewables are responsible for the downward trend in emissions.

Industry

German industry as a whole was responsible for almost 21% of the country's greenhouse gas emissions in 2015. Emissions from industrial processes are strongly linked to production levels. Carbon dioxide (CO₂) emissions are particularly indicative of the economic trend for the mineral, chemicals and metal manufacturing industries.

When measured against economic output, greenhouse gases as a whole have declined. Whereas in 1991 around 0.59 Mt CO₂e of greenhouse gases was released for every billion euros (EUR), this had fallen to only 0.33 Mt CO₂e in 2015, a decrease of some 45 %.¹²

Trade, commerce and services sector

Germany's economic structure is dominated by the trade, commerce and services sector, which, at 69 %, made the greatest contribution to value added in 2016. This sector also had the largest number of employees. Measured against economic output, this sector's share of greenhouse gases is relatively small, at only about 4 %. Climate action and the energy transition require considerable willingness by German industry to change and adapt, but they also offer great opportunities. Increases in productivity and efficiency and reductions in the demand for energy and resources offer cost advantages and can increase competitiveness.

Agriculture

Agriculture contributed about 8 % to greenhouse gas emissions in Germany in 2015. According to projections in 2017, the absolute quantity of greenhouse gases from agriculture will remain relatively constant in coming decades. The decrease in total emissions gives agriculture a growing percentage share in German greenhouse gas emissions, so agriculture is increasingly important for climate action in Germany. Greenhouse gas emissions in agriculture are primarily caused by the use of mineral and organic fertilisers, livestock raising, ploughing up grassland and draining bog lands. At the same time, agriculture is particularly affected by climate change, which can impact on crop yields.

¹² Federal Ministry for Economic Affairs and Energy (2016a).

Forestry

Forests are still natural sinks for carbon dioxide in Germany. In 2015, a total of 57.7 Mt CO₂e was captured in German forests. The sink performance of forests in Germany is trending downward because their trees are relatively old, so that the amount of wood extracted currently outstrips the rate of new growth. When accounting for forestry's contribution to climate change mitigation, it must be kept in mind that emissions that are avoided by producing materials and energy from wood that is directly related to the raw material supplied by the forestry sector are not classified under that source category. Instead, the reduced emissions are reflected in the energy industry, construction and housing, transport and industry business sectors or source categories. The extent, direction and speed of current climate change also threaten to exceed the ability of forests to adapt. This particularly affects mountain forests in the Alps, where climate changes are more pronounced than in the lowlands.

Waste/wastewater

Waste management and the circular economy are making a major contribution to climate action. Recycling and recovery rates in Germany have continued to increase in recent years. Various methods for recovering biowaste and green waste also play an important role. The Circular Economy Act (Kreislaufwirtschaftsgesetz) has required biowaste and green waste to be collected separately since 2015. Landfilling untreated organic waste has been prohibited since 2005. This avoids most emissions of methane gas from waste, which is harmful to the climate. According to new calculations by the Federal Environment Agency (UBA), methane emissions from landfills have fallen by around 75 %, from 1.33 million tonnes in 1990 to 0.36 million tonnes in 2015. The percentage share of greenhouse gas emissions from waste is therefore very low. Municipal wastewater treatment, to which 96 % of people living in Germany are connected, normally takes place under aerobic conditions, so methane emissions are very low.

1.2 Information on the Greenhouse Gas Inventory

As a Party to the UN Framework Convention on Climate Change, Germany has been required to prepare inventories of national greenhouse gas emissions since 1994. Germany submitted its latest National Inventory Report (NIR 2017) on 15 April 2017. It describes the methods and data sources on which the calculations of German greenhouse gas emissions are based. It is also the basis for this National Communication. It contains information on the direct greenhouse gases (GHG) carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃) in table form.

Reduction commitments

In the context of the Kyoto Protocol, the European Union pledged to reduce its greenhouse gas emissions during the second commitment period from 2013 to 2020 by 20 % from the base year (1990 or 1995). Under the EU Emissions Trading Scheme, emissions in selected industries and production processes are capped by quantity limits throughout the EU. The reduction commitments in the other sectors are distributed among the Member States. As part of effort sharing within the EU, Germany has undertaken to reduce emissions in the sectors not regulated by emissions trading by 14 % between 2005 and 2020.

Shares of greenhouse gases

Carbon dioxide (CO₂) was also the primary cause of greenhouse gas emissions in 2015, with a share of 87.8 %. Most of them came from stationary and mobile combustion of fossil fuels. Methane (CH₄) emissions, most of which are caused by livestock raising, fuel distribution and landfills, accounted for a 6.2 % share in 2015. Most emissions of nitrous oxide (N₂O) came from agriculture, industrial processes and the combustion of fossil fuels, contributing 4.3 % to greenhouse gas emissions. Fluorinated gases (known as F-gases) contributed about 1.7 % to total emissions; NF₃, a greenhouse gas which has only recently been included in the reporting, contributed a negligible share of 0.001 %.

Emission trends

Greenhouse gas emissions in Germany were 27.9 % lower in 2015 than in 1990. Electricity generation achieved the greatest reductions in emissions by using fewer fossil fuels. Greenhouse gas emissions in the area of industrial process emissions remain practically constant. Greenhouse gas emissions are also stagnating in the transport sector, with just less than 0.7 Mt CO₂e more emitted in 2015 than during the previous year. Increases in road transport volumes are responsible for the rise. This means that the previous year's trend continues. Emissions by agriculture are also stagnating and were up by about 0.5 % or almost 0.5 Mt CO₂e in 2015. The main causes of this trend are increased emissions from liming of soil and urea application, as was the case for the previous year.

1.3 Policies and measures

The federal government approved Germany's long-term climate strategy in November 2016 in the form of the Climate Action Plan 2050. It updates the decisions taken on the energy transition in 2010 and 2011 and for the first time defines a comprehensive climate strategy with the goal of becoming largely greenhouse gas neutral by mid-century. Intermediate targets are derived from it, particularly for 2030, by which time Germany intends to achieve a reduction in greenhouse gases of at least 55 % compared with 1990 levels. The plan also spells out emission reduction targets for all relevant sectors for 2030 and sets up a process for monitoring and for participation by the public. The first programme of measures under the Climate Action Plan 2050 will be presented at the end of 2018. It will specify measures to ensure that targets are met by 2030.

By adopting the Climate Action Programme 2020 back in 2014,¹³ the German government approved reduction measures to supplement existing strategies and decisions. The intention was to ensure that the national greenhouse gas reduction target of 40 % by 2020 was met, since the 2013 Projections Report had indicated that the target would probably not be achieved with the measures that had been put in place at that time. Further reductions are expected as a result of the Action Programme. However, as things now stand (2017 Projections Report),¹⁴ a mitigation gap of up to 5 % remains. The question of whether further measures should be taken – and if so which ones – in order to close that gap is being considered.

In addition to measures in the energy sector, the Climate Action Programme 2020 – like the Climate Action Plan 2050 – now includes more measures to reduce non-energy-related greenhouse gas emissions.

¹³ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014b).

¹⁴ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017), English version will be available in due course at <http://acm.eionet.europa.eu/>.

Other integral parts of the German government's climate policy include – along with targets and measures – regular participation by the public, monitoring of implementation, and regular national reporting.

The Emissions Trading Scheme remains one of the key cross-sectoral measures at the European level. In Germany, it covers the majority of greenhouse gas emissions by the energy industry, the country's most energy-intensive industry, and has also included aviation since 2012. Major reforms, including the extension of allowance trading to additional sectors, were adopted and implemented in 2013 when the third phase of EU emissions trading began.

Many additional European and German measures address other sectors relevant to climate action, such as energy; buildings; transport; industry; trade, commerce and services; agriculture and forestry; waste management and water management. The following measures have either been amended or adopted for the first time in recent years:

- The Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz) has defined quantity corridors for capacity increases for wind power and photovoltaic systems since 2017, while the support arrangement for large systems has been converted from a guaranteed feed-in tariff to a tendering model.
- The National Action Plan on Energy Efficiency (NAPE) includes a tendering mechanism for funding energy efficiency projects.
- In the buildings sector, non-residential buildings used for commercial purposes are increasingly being addressed, for example in the CO₂ building refurbishment programme or the BAFA funding programme for energy advice.
- The toll charge for heavy goods vehicles has been expanded, and new initiatives to promote electric mobility have been launched.
- Funding programmes such as the Special Energy and Climate Fund are making an important contribution to achieving German climate targets.
- Measures to prevent avoidable food waste, which is responsible for greenhouse gas emissions totalling about 19 million tonnes annually¹⁵ in Germany, will continue. This includes the Too Good for the Bin initiative.

Other initiatives have been taken by the Länder and by local authorities. All 16 German Länder have their own concepts, programmes, plans or legislation relating to climate action. Many local authorities are also setting targets for themselves and developing their own climate action strategies and measures.

1.4 Projections and impacts of measures

In preparation for the 2017 German Projections Report, the Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) commissioned a research consortium to prepare scenarios to predict how greenhouse gas emissions in Germany might develop from 2005 to 2035. Firstly, it created a “with-measures” scenario (WMS), which includes new climate and energy policy measures in various sectors introduced by 31 July 2016 and existing measures that have been substantially changed by the same date. Secondly, it modelled a “with-additional-measures” scenario (WAMS) which

¹⁵ UBA Texte 85/2016.

includes primarily the policy measures that are set out in the interministerial Climate Action Programme 2020 (BMUB 2014) and the National Action Plan on Energy Efficiency (BMWi 2014) but have not yet been implemented.

With-measures scenario

For total greenhouse gas emissions (not counting land use, land-use change and forestry, and international aviation and maritime transport), the with-measures scenario shows a 34.7 % reduction of greenhouse gases in 2020 compared with 1990. Under the scenario, emissions decrease by about 41 % up to 2030 and by more than 46 % up to 2035. If the sensitivities analysed in the report are taken into consideration, the possible corridor for emissions reduction in 2020 is between 33.7 % (stronger economic growth) and 37.5 % (lower electricity export balance) of the 1990 level.

With-additional-measures scenario

Under the with-additional-measures scenario there is a reduction in total greenhouse gas emissions (excluding land use, land use change and forestry, and international aviation and maritime transport) of 35.5 % in 2020 as compared with 1990. By 2030 there is a reduction of over 45 % and by 2035 of almost 53 % compared to 1990. If the sensitivities analysed in the report are taken into consideration, the possible corridor for emissions reduction in 2020 is between 34.5 % (stronger economic growth) and 38.4 % (lower electricity export balance) of the 1990 level.

The German government does not fully endorse the results of the scenarios for the trend in greenhouse gas emissions in Germany for the 2005 to 2035 period. However, it will include the Projections Report's research results in its future considerations.

1.5 Vulnerability, impact of climate change and adaptation measures

Current simulation calculations indicate that the climate in Germany will experience additional changes. These include a further rise in temperature and an increase in temperature extremes, particularly in the form of more frequent heatwaves. It is assumed that the total mean annual precipitation will not change substantially up to 2050, although the seasonal distribution will.

The Federal Ministry of the Environment commissioned a network of 16 higher federal authorities and institutions to prepare a cross-sectoral vulnerability analysis covering all of Germany for the period up to 2020. Six trends that could have particularly critical impacts on certain fields of action and regions were identified.

In 2015, the German government published the first progress report on the German Strategy for Adaptation to Climate Change and adopted an additional package of measures as part of the second Adaptation Action Plan. Whereas it devoted the last 10–15 years to strategy development and the closing of knowledge gaps as its top priority, the focus of work in recent years has shifted to starting to implement the strategy. Longer-term tasks involved in adaptation to climate change are to be implemented under the second Adaptation Action Plan, and various ministries within the federal government will assume responsibility for them. This includes embedding adaptation to climate change on an operational level, for example in the federal administrations responsible for infrastructure, preparing regular monitoring reports on developments relating to climate change impacts and adaptation measures and conducting regular vulnerability analyses (every five to seven years).

To further consolidate the activities of the German Strategy for Adaptation to Climate Change, the federal government will create a comprehensive portfolio of climate services and services to support adaptation, whose main task is to deliver the required climate services reliably over the long term. The Länder have also begun to develop and implement their own policies and strategies for adapting to climate change.

1.6 Financial support and technology cooperation

The German government increased its funding to support developing countries, emerging economies and countries in transition up to 2016 in reducing greenhouse gases, adapting to the effects of climate change, and promoting forest conservation. In 2016 it provided budget funds in the amount of EUR 3.362 billion or USD 3.719 billion for international climate financing – a 25.2 % increase from the previous year. Technology transfer and capacity building are integral parts of almost all of the German government's international development cooperation projects

The German government supports the implementation of Nationally Determined Contributions (NDCs), which were agreed to by the Parties to the Paris Agreement, in its partner countries. It already supported around 40 countries in the development of their Intended Nationally Determined Contributions (INDCs) ahead of the Paris Agreement's entry into force.

As part of its international development cooperation, Germany has increased its financing for climate change mitigation projects in developing countries, emerging economies, and transition countries. The work emphasises climate policy, national mitigation strategies, renewables, increased energy efficiency, adaptation to the impacts of climate change, climate risk insurance, and the protection of forests and biodiversity, including **Reducing Emissions from Deforestation and Forest Degradation** and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+), which will have significant positive effects on both mitigation and adaptation to climate change. The German government strives to provide balanced support for mitigation and adaptation. Around 55 % of the funds (EUR 1.55 billion) was spent on bilateral mitigation activities and around 45 % (EUR 1.27 billion) was spent on bilateral adaptation activities in 2016.

Multilateral cooperation takes place through organisations such as the Green Climate Fund (GCF), the Global Environment Facility (GEF), the Adaptation Fund (AF), and the Climate Investment Funds (CIFs) and Forest Carbon Partnership Facility (FCPF) of the World Bank.

Technology transfer is an integral component in virtually all of the German government's climate-related bilateral cooperation projects. Germany is involved in technology cooperation, for example, through its committed support for the UNFCCC Technology Mechanism, in the Technology Executive Committee (TEC) and in the Climate Technology Centre and Network (CTCN), as well as with the German Climate Technology Initiative (DKTI).

1.7 Research and systematic observation

Many ministries in Germany, and their associated institutions, promote research in the areas of renewables, energy efficiency, sustainable mobility, sustainability, climate change and adaptation to climate change. For example, questions related to climate change are being investigated under the Third Framework Programme entitled Research for

Sustainable Development (FONA³) and the Sixth Energy Research Programme, as well as in the sectoral research programmes of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, the Federal Ministry of Economic Affairs and Energy and the Federal Ministry of Food and Agriculture.

The diverse range of research activities includes the following:

- The climate system, variability and interactions in the Earth system
- Observation and data management
- Climate impact research
- Energy and mitigation research, including technological research
- Adaptation to climate change and assessment of climate impacts
- Socio-economic research on the causes and effects of climate change

Germany is also continuing to increase its support for the Global Climate Observing System (GCOS). The Deutscher Wetterdienst (DWD) and various German research institutions support the GCOS Surface Network, the GCOS Upper-Air Network for atmospheric monitoring, the Global Ocean Observing System and the Global Terrestrial Observing System (GTOS). The Interministerial Working Group on Adaptation Strategy has provided political support for the national implementation of German participation in the GCOS pursuant to Article 6 of the UN Framework Convention on Climate Change since October 2015. Germany supports the establishment and operation of observation systems and systems for data management and climate monitoring in developing countries.

1.8 Education, training and public awareness

The German government supports sustainable development through targeted educational activities. A number of concepts and projects have been developed to promote environmental education in schools and as part of continuing professional development. Many education projects in Germany also receive funding under the National Climate Initiative (NKI).

The German government supports climate action and the energy transition by conducting public awareness campaigns and providing materials to inform and educate the public. Communication and dialogue make members of the public aware of the need for active climate policy. At the same time, they learn about areas where they themselves can take action. Major climate programmes such as the Climate Action Plan 2050 are also developed with public participation.

Active public awareness work is also an integral part of funding programmes and projects in the area of climate action. Professional communication services are provided for almost all projects in the areas of national and international climate action, the energy transition and mobility.

2 National circumstances

2.1 Key data

2.1.1 Environmental protection as a national objective

Protection of the natural resources that sustain life has been enshrined as a national objective in Article 20a of the Basic Law – the Federal Republic of Germany's constitution – since 1994.

2.1.2 Government structure

The Federal Republic of Germany is a federation of 16 states (“Länder”). The Basic Law governs the division of responsibilities between the federal government and the Länder. The Länder usually have a three-tier administrative system divided into Land (state) government, regional councils (Regierungspräsidien), and administrative districts (Landratsämter) or urban districts (Stadtkreise). As a rule, the Länder decide for themselves how their administrations are to be structured.

The German government and the Länder cooperate on environmental policy in specific working groups such as the Federal-Land Working Group on Climate and Sustainability (BLAG KliNa). Federal-Land summits to implement the Energiewende, Germany's energy transition, have been held twice a year since 2012 at the invitation of the Chancellor.

2.1.3 Legislation and enforcement

Legislative authority is divided between the federal government and the Länder. The federal government has exclusive powers of legislation in certain areas allocated to it under the Basic Law. This is not the case for environmental protection.

On the contrary, the individual areas of environmental law are subject to concurrent legislation. The federal government has the power of concurrent legislation when uniform regulation is necessary. This allows it to have a decisive influence on environmental legislation and to transpose EU directives related to the environment.

All federal laws are submitted to the Bundestag (lower house of parliament) and the Bundesrat (upper house of parliament). Depending on their content, some laws require the explicit approval of the Bundesrat (Zustimmungsgesetze), whereas on other types of law the Bundesrat can merely express its opinion (Einspruchsgesetze).

The Länder have primary responsibility for the enforcement of laws. They implement their own Land laws and also implement most federal legislation pursuant to Article 83 of the Basic Law. Exceptions to this, under which the federal administration enforces laws, include those relating to the Foreign Service, the Federal Tax Administration, the Federal Border Police or the Federal Waterways and Shipping Administration.

As a member of the European Union, the Federal Republic of Germany transposes the Community's agreements. Like the German Basic Law, the EU Treaty and the Treaty on the Functioning of the European Union contain the overarching objectives of sustainable development and improving the quality of the environment. The EU and its Member States share responsibility for areas of importance for climate action, such as the environment, energy, transport and agriculture. This means that the EU and the Member States are

entitled as a matter of principle to lay down rules and regulations. If the EU fails to fulfil its responsibility in one of the areas, regulation is up to the Member States.

Most of the environmental laws in Germany are based on EU decisions in the form of directives, which the Member States must transpose into national legislation, or regulations, which immediately have binding legal force.

A publication entitled “A Guide to Environmental Administration in Germany” provides a detailed summary of the structure and functioning of the environmental administration in Germany and the role of the European Union.

2.2 Population profile

Germany’s population was 82 million in 2015, according to the Federal Statistical Office.¹⁶

The 13th population projection for Germany, which was jointly prepared by the Federal Statistical Office and those of the Länder, and an updated version of it contain the potential population trend up to 2060. Germany’s population increased from 2011 to 2015. Strong net immigration from 2010 to 2015 put an end to the decline in population between 2003 and 2010. However, the fundamental causes of the decline in population persist. Depending on the extent of net immigration, the population is projected to continue to increase from the 2015 level of 82 million for another five years or so and then decrease again.

The updated version forecasts that it will fall below the 2015 level starting in 2035 and will be about 76.5 million in 2060. The original forecast, which did not include 2015, put the population in 2060 at between 67.6 million (continuity with weaker immigration) and 73.1 million (continuity with stronger immigration).¹⁷

¹⁶ Federal Statistical Office (2016a).

¹⁷ Federal Statistical Office (2015a).

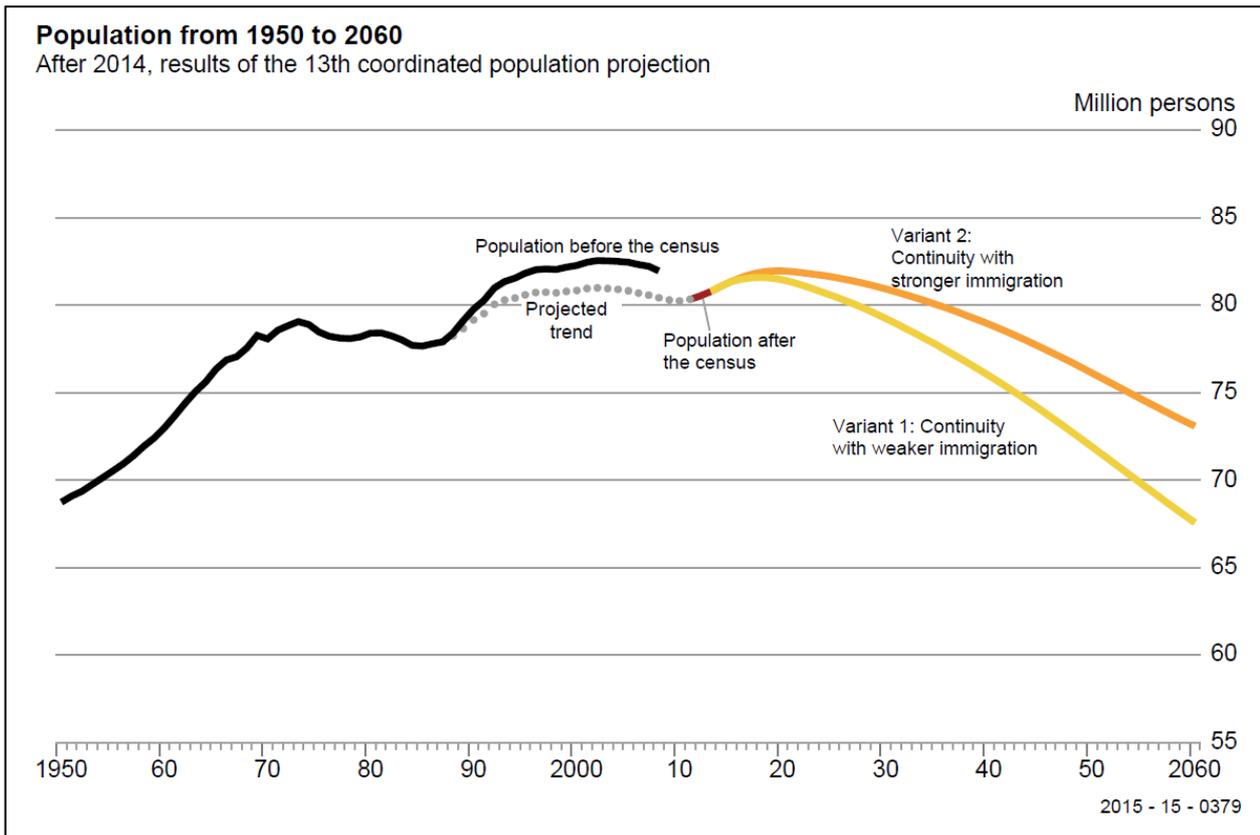


Figure 2: Population in Germany from 1950 to 2060; after 2014, results of the 13th population projection.¹⁸

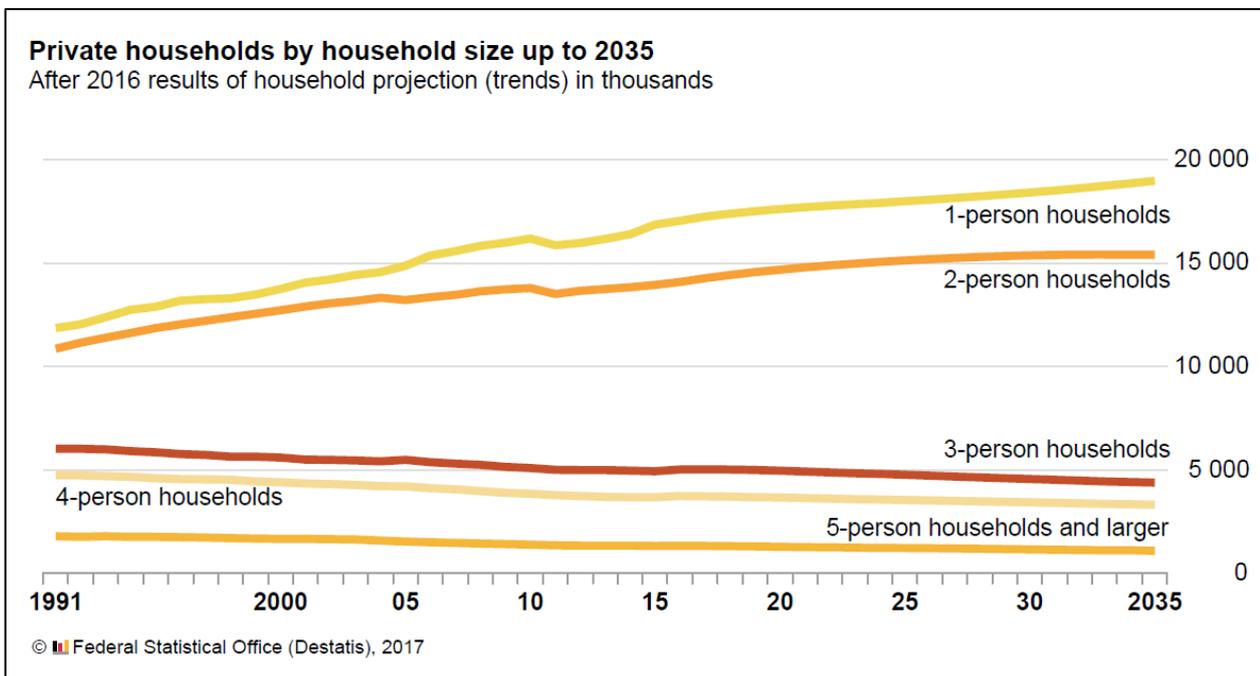


Figure 3: Trend in private households by household size through 2035 (trends variant, in thousands), Germany.¹⁹

Although the population is decreasing, the number of households continues to grow. The trend is for households to get smaller in Germany. The largest group is single-person

¹⁸ Federal Statistical Office (2015a).

¹⁹ Federal Statistical Office (2017b).

households, and their share continues to grow. Both younger people and increasing numbers of older people are living alone. The number of two-person households is also increasing. In contrast, the number of households made up of three or more people is decreasing.²⁰

2.3 Economic development

Gross domestic product (adjusted for inflation) increased by 1.9 % in 2016, the seventh year in succession.²¹ The German government anticipates that gross domestic product (GDP) will increase by approximately 2 % in 2017.²² Government net lending/borrowing was 0.8 % of GDP,²³ while government debt was 68.3 %.²⁴ Structural net borrowing by the government was around 0.1 % of GDP, according to provisional data for 2016. As in previous years, the requirements of the debt rule were amply fulfilled.²⁵

Net lending/borrowing by the government is projected to be 0.25 % of GDP in 2018 and 2019 and 0.5 % of GDP in 2020 and 2021, while public debt will be pushed back to 57 % of GDP by 2021.²⁶

German companies are very well positioned in the international growth markets, and their competitiveness is outstanding. They remain highly innovative thanks to research and development.

A total of 43.6 million people²⁷ were gainfully employed in 2016, and the German government's autumn forecast predicts a further increase of at least 660,000 people in 2017.²⁸ In December 2016, some 31.8 million people were working in jobs subject to mandatory social security contributions and 7.6 million people were in marginal employment, 35 % of whom had second jobs.²⁹ This meant that not only the total number of gainfully employed people but also the number of people working in jobs subject to mandatory social security contributions were at their highest levels ever.³⁰

2.4 Geography and land use

The total area of Germany was 357,409 km² in 2015. Agricultural land (including bog and heath land) accounted for approximately 52 % (184,332 km²). This means that Germany's agricultural land area has decreased by 921 km² since 2011. In contrast, the area under forest has increased slightly by a net 500 km² from the 2002 level.³¹ Almost 32 % of Germany was covered by forest in 2015 (114,191 km²). Of all the types of land cover in Germany, water accounts for 8,552 km² or 2 %, which is the smallest percentage share. Compared with 2011, the area covered by water has increased by 191 km², largely as a result of flooding and renaturing of former sand, gravel and lignite extraction sites.

²⁰ Federal Statistical Office (2017b).

²¹ Federal Ministry for Economic Affairs and Energy (2017).

²² Federal Ministry for Economic Affairs and Energy (2017b).

²³ Federal Statistical Office (2017c).

²⁴ Deutsche Bundesbank (2017).

²⁵ Federal Ministry of Finance (2017a).

²⁶ Federal Ministry of Finance (2017b).

²⁷ Calculation based on the domestic concept (gainfully employed people working in Germany).

²⁸ German government (2017a).

²⁹ Federal Employment Agency (2017).

³⁰ Federal Ministry of Economic Affairs and Energy (2017a).

³¹ This information from the Federal Statistical Office differs from the data used below to calculate CO₂ sequestration by forests, which comes from the federal forest inventory.

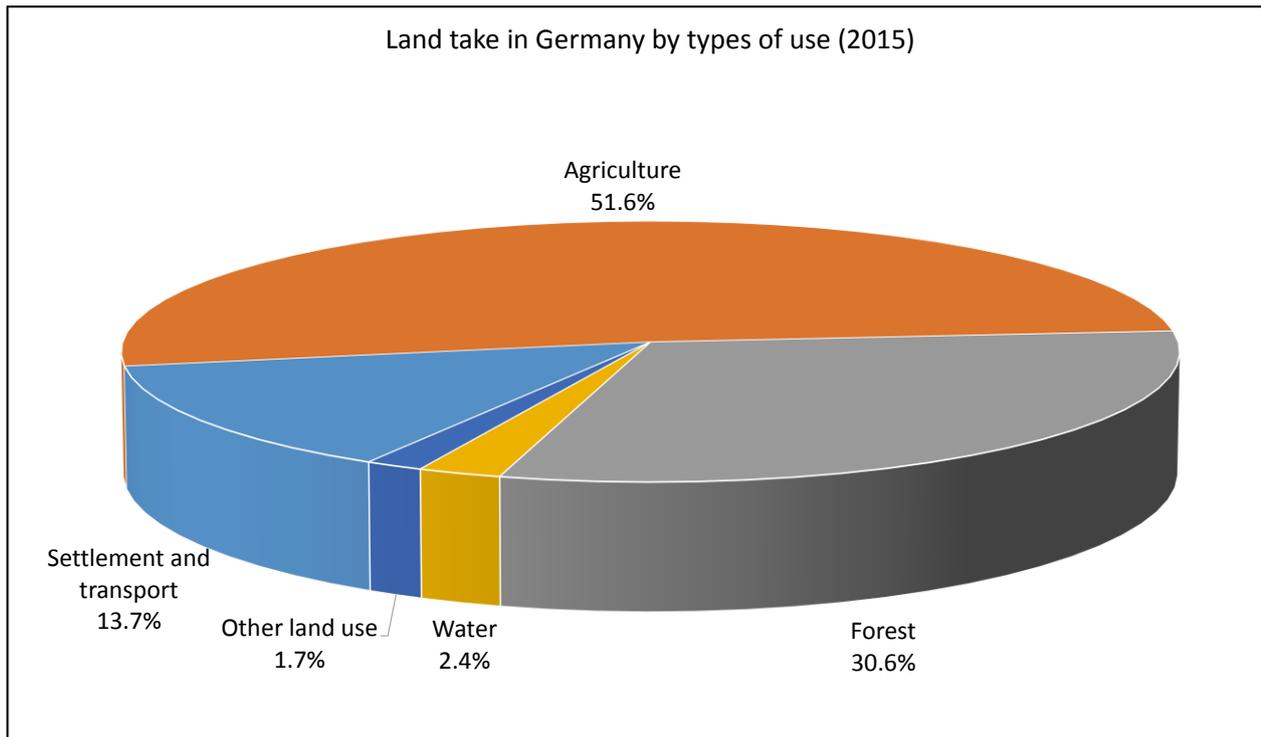


Figure 4: Land take in Germany in 2015 by type of use³²

The land used for settlement and transport in 2015 amounted to around 14 % of the total area of Germany (49,066 km²). This is an increase of 933 km² since 2011. However, the rate of increase has slowed: whereas the amount of land used for settlement and transport purposes increased by 115 hectares (ha) daily during the 2001-2004 period, the daily increase for 2012-2015 was only about 66 ha. However, this trend is not sufficient to meet the German government's target of reducing land take to 30 ha per day by 2020.

2.5 Climate and climate changes in Germany

Germany is part of the temperate, rainy climate zone of the mid-latitudes. The annual mean temperature between Sylt (an island in northern Germany) and the Zugspitze (Germany's highest peak) from 1961 to 1990 was 8.2 degrees Celsius. The sun shines an average of 1,544 hours per year. Prevailing westerly winds carry moist air masses in from the Atlantic throughout the year, bringing up to 789 l/m² of annual precipitation. The maritime influence generally keeps winters mild and ensures that summers are not too hot.³³

The Deutscher Wetterdienst (German Meteorological Service, DWD), has over 150 years of experience in observing the weather and climate. To increase the reliability of the available information, DWD has been supplementing its basic daily digital data by systematically digitalising historical weather records since 2005. The introduction of meteorological services led to the creation of a uniform observation network (at least in some places), so measurements are also representative beyond the individual location.

³² Federal Statistical Office (2015b) authors' graphic.

³³ Deutscher Wetterdienst (2016b).

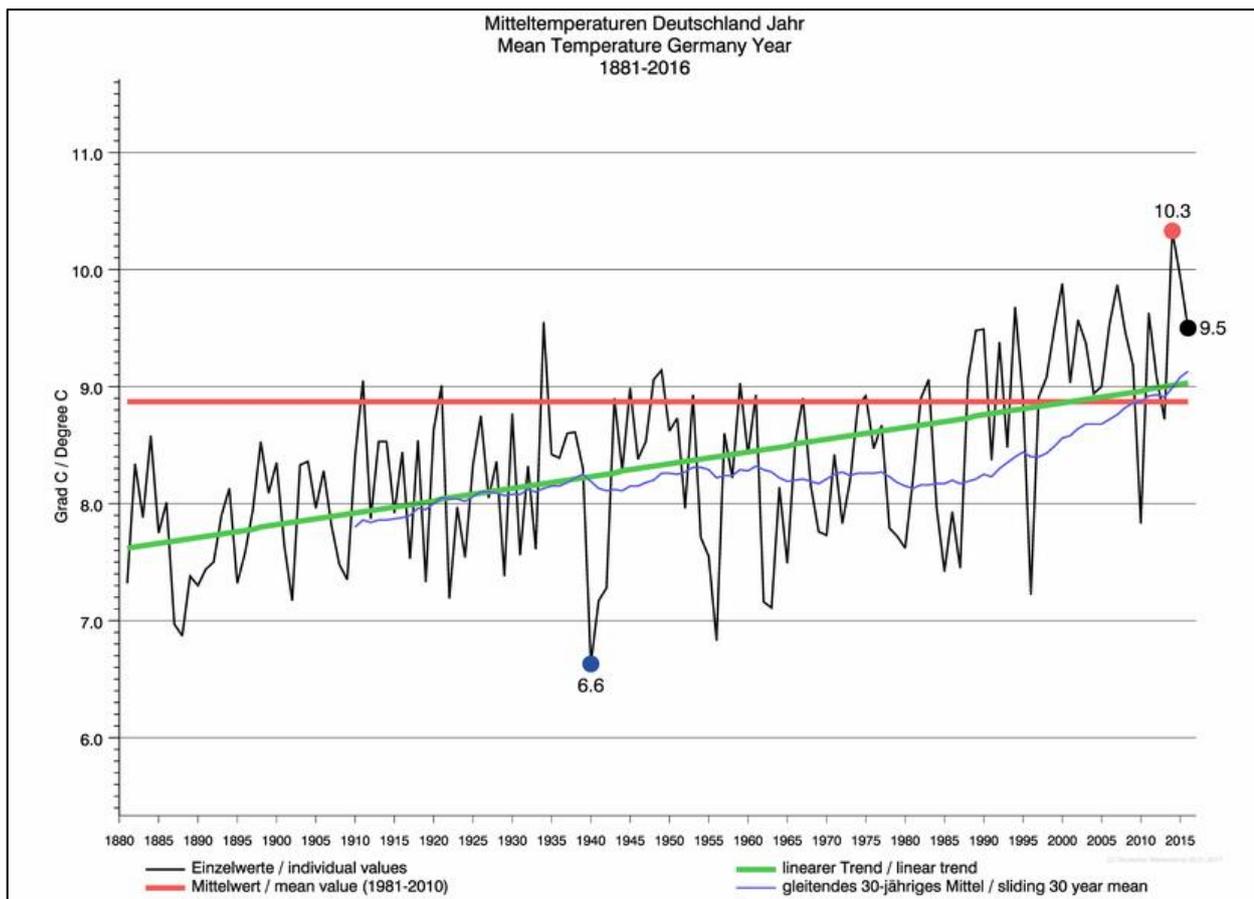


Figure 5: Annual mean temperature in Germany³⁴

Germany's mean air temperature rose by 1.4 degrees Celsius between 1881 and 2015. The multi-year mean for the 1961-1990 reference period (8.2 degrees Celsius) has risen to 8.9 degrees Celsius during the more recent 30-year period of 1981-2010. The most pronounced increases since 1881 have been 1.5 degrees Celsius in the West German lowland bay (Westdeutsche Tieflandsbucht), the low mountain ranges left of the Rhine and the lowlands of the Upper Rhine rift, while the slightest increase (0.9 degrees Celsius) has been in the North-East German lowland.³⁵

Changes in precipitation have also been observed in Germany. The areal mean annual precipitation in Germany has increased by over 10 % since the late 19th century (1881). At 101 mm, target precipitation in 2015 exceeded the level for the 1961-1990 climate reference period by 52.3 %.

The average number of hot days (daily maximum air temperature ≥ 30 degrees Celsius) for Germany as a whole has increased since the 1950s from about three days per year to the current average of nine days per year. The average number of "ice days" (daily maximum air temperature < 0 degrees Celsius) fell from 28 days to 19 days during the same period. The greatest number of heat situations also occur in the warmest parts of Germany. During the 1961-1990 period, the average number of hot days in the lowlands of the Upper Rhine rift, the West German lowland bay, and the South-Eastern basin and hills increased from five to nine days per year. During the 1981-2010 period, events of this kind increased from an average of eight to nine and to as much as 13 days per year in the lowlands of the

³⁴ Deutscher Wetterdienst (2016b).

³⁵ Deutscher Wetterdienst (2016a).

Upper Rhine rift.³⁶ The frequency with which various precipitation thresholds are exceeded has increased slightly, but those trends cannot be considered statistically significant due to their great variability over time and in different places. The trend for storm activity shows a progression similar to that for mean wind speed, without a major trend being apparent.

Chapter 7.3 and the 2015 Monitoring Report on the German Strategy for Adaptation to Climate Change provide a detailed overview of projected climate changes in Germany.

2.6 Energy

2.6.1 Restructuring the energy system

The initial successes of Germany's energy transition, under which the government set the goal of making Germany one of the world's most energy-efficient and environmentally-friendly economies while keeping energy prices competitive and maintaining a high level of prosperity, are already apparent, even though adjustments still need to be made in some areas. Efforts to increase the use of renewable energy are progressing. The power supply is reliable, even though eight nuclear power plants were permanently taken off line in 2011. The foundation has also been laid for accelerated expansion and upgrade of the grid.

The increasing burden of energy costs remains a challenge, particularly in the electricity sector. More work must be done to make further reductions in greenhouse gas emissions and achieve the stated targets by 2020 and beyond.

The trends mentioned here are described in greater detail in the sections below, as well as in Chapter 4.1.

2.6.2 Energy consumption by sector and energy source

Primary energy consumption (up to 2016)

Primary energy consumption is the net balance of domestically produced energy and energy traded with other countries minus marine bunkers and taking into account changes in inventory. It includes both primary and secondary sources. Primary energy consumption in Germany has decreased slightly since the early 1990s. A portion of this effect is attributable to the determination of primary energy consumption using the physical energy content method. As a result of this calculation method, the previous expansion of renewable energy sources (assessed by definition as having a conversion frequency of 100 %) leads to lower primary energy consumption by squeezing out other energy sources with a lower conversion efficiency. Improvements in efficiency are also responsible for this trend, however.

Provisional data indicates that primary energy consumption was 13,451 petajoules (PJ) in 2016,³⁷ up slightly from the previous year. According to the Working Group on Energy Balances (AGEB), many factors were responsible for that increase, including a positive economic trend, an increase in population, and colder weather than the previous year with the resulting rise in demand for heating energy.³⁸

³⁶ Deutscher Wetterdienst (2016a).

³⁷ AGEB (2017b).

³⁸ Ibid.

The German government's aim is a 20 % reduction in primary energy consumption by 2020 compared with the base year 2008. However, the reduction achieved up to 2016 was only 7 %.

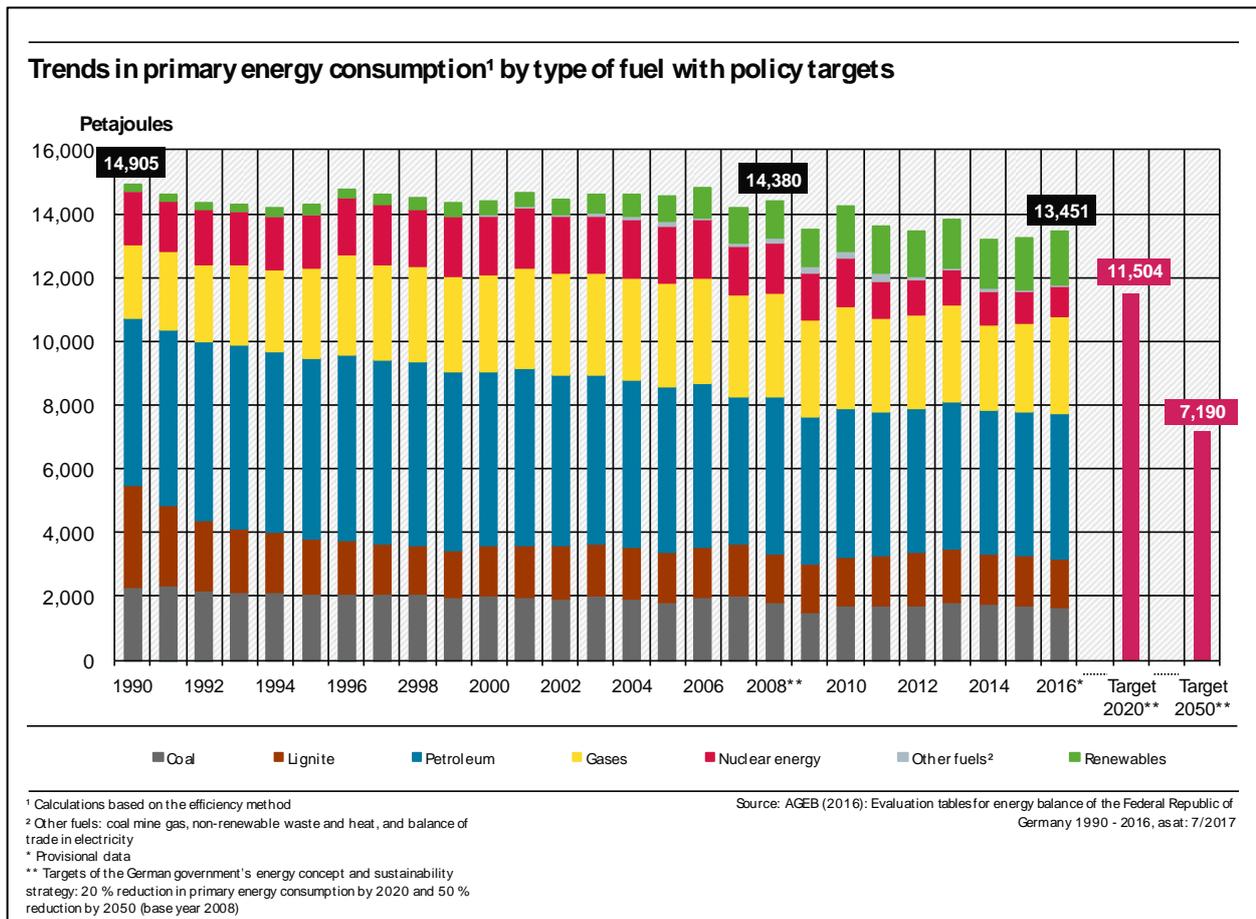


Figure 6: Primary energy consumption by energy source³⁹

Final energy consumption (up to 2015)

Primary energy consumption in Germany has decreased little if at all since the early 1990s. Larger amounts of energy are being used more efficiently and conserved in some cases, but economic growth and increased consumer spending are preventing greater reductions in energy use. When considering the limited period of one year, weather – which has a major influence on demand for heating energy – considerably affects the trend for energy consumption. The sectoral structure of final energy consumption has changed since 1990: the importance of industry has declined. Its share in total final energy consumption decreased from 31.4 % in 1990 to 28.6 % in 2015. The trade, commerce and services sector experienced a similar trend, falling from 18.5 % to 16.0 %. Private households' share, which increased by 0.9 percentage points to 25.9 %, has hardly changed. The transport sector has actually experienced an increase from 25.1 % to 29.5 %.

³⁹ AGEB (2016); AGEB (2017b).

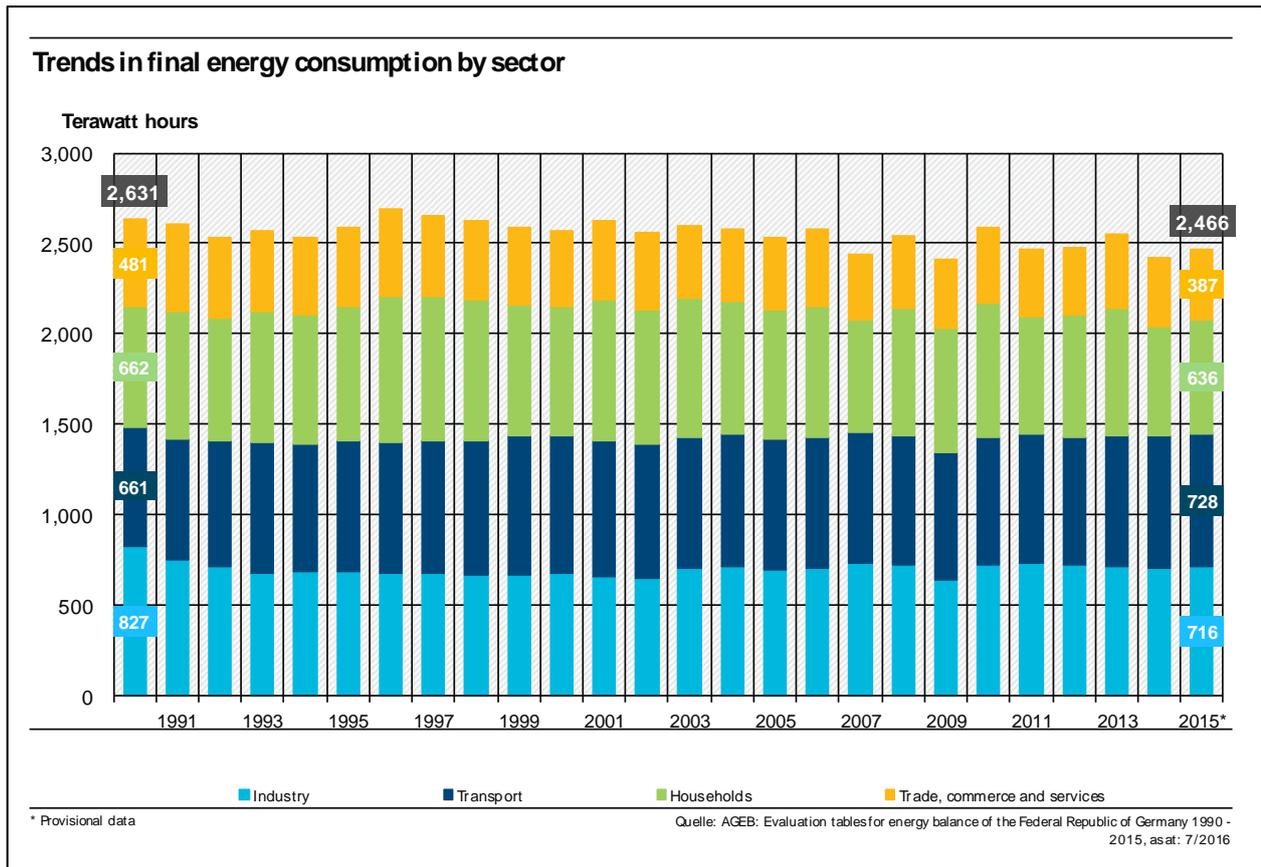


Figure 7: Trends in final energy consumption by sector⁴⁰

Final energy consumption in the sectors by energy source (up to 2015)

Petroleum is the most commonly used fuel in all sectors. Its share was around 37 % in 2015, followed by natural gas with a share of 25 % and electricity with a 21 % share. Consumption of coal and district heating was approximately equal at 5 %, and renewables in the form of biomass accounted for 7 %. Other energy sources such as waste and waste heat were used only in industry and amounted to less than 1 % of total final energy consumption.

Final energy consumption in industry during the reporting period decreased considerably starting in 1990. This is primarily due to the decline of industry in the former East Germany between 1990 and 1993. But a downward trend for consumption in the years leading up to 2015 also means that industry is no longer the sector with the highest consumption. Two-thirds of final energy consumption was for process heat. Mechanical energy, for example to drive motors or machines, accounted for about one-quarter of consumption, while space heating was responsible for a negligible share. The most important energy sources are natural gas and electricity at over 30 % each, followed by lignite and coal at 17 %.

Fuel consumption in the transport sector has risen slightly over the past 25 years. More than 90 % of the fuel used is based on petroleum, with biofuels and electricity playing a lesser role. Almost all of the energy consumed in the transport sector is used to produce mechanical energy, although on average less than half of the energy consumed by internal combustion engines actually drives the vehicle. Most of it is lost as waste heat. The German government's target is a 10 % reduction in final energy consumption in the transport sector

⁴⁰ AGEB (2016).

by 2020 compared with 2005 levels. However, there had been a slight increase of about 1.3 % by 2015.

Private households tended to use a bit less energy in 2015 than in 1990. Space heating now accounts for about 69 % of energy consumption in households, among other reasons because the living space to be heated has increased over the years. The fuel with the highest consumption is natural gas at 37 %, followed by heating oil at 21 %. Renewable heating and district heating are also increasingly being used in this sector.

The trade, commerce and services sector is also dependent on heating behaviour. Space heating still accounts for almost half of final energy consumption in this sector. Electricity has the largest relative share due to greater use of electricity for lighting and to produce mechanical energy. However, final energy consumption in this sector has decreased since 1990.

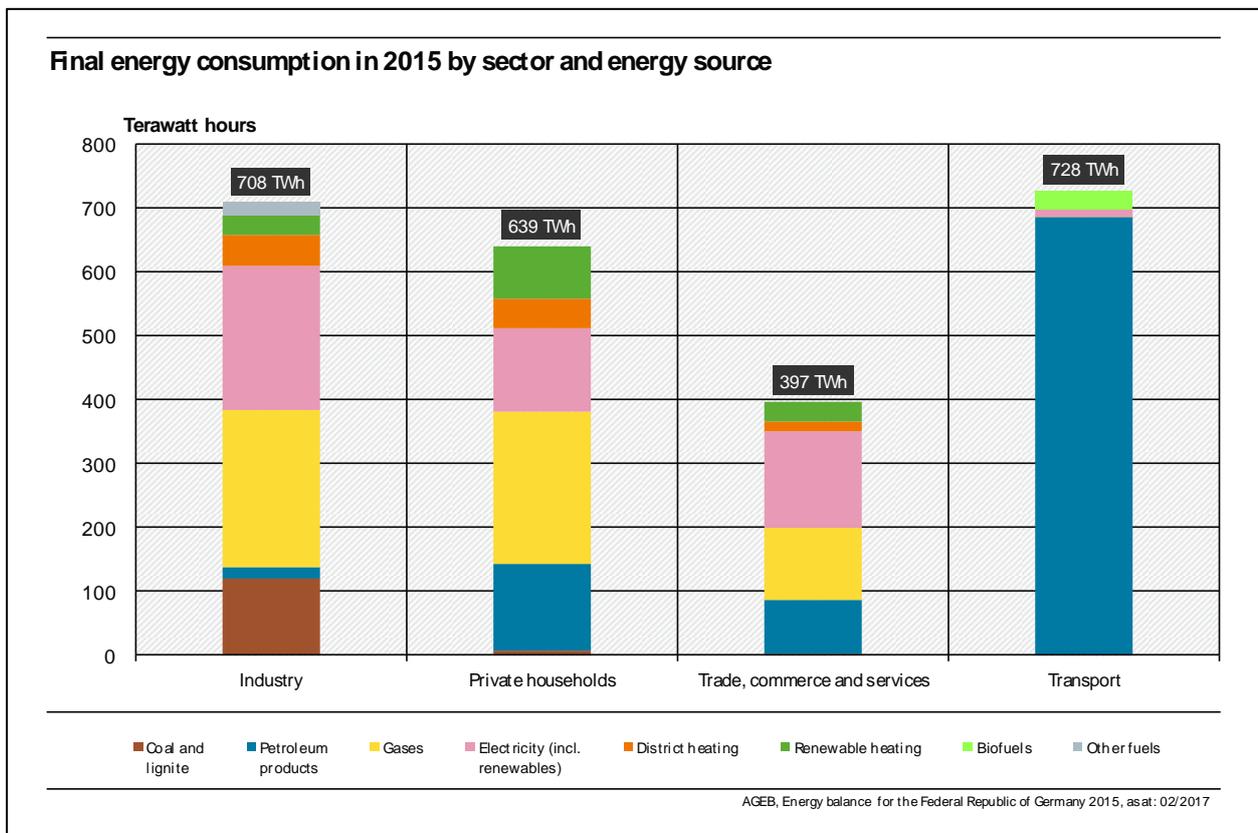


Figure 8: Final energy consumption in 2015 by sector and energy source⁴¹

2.6.3 Electricity generation by energy source

It is estimated that gross electricity generation in Germany was 648 TWh in 2016.⁴² After factoring in the record power exchange balance of imports, (-54 TWh), gross domestic electricity consumption was 595 TWh (2015: 595 TWh).

Gross electricity generation in Germany increased by 18 % or 99 TWh between 1990 and 2016. Gross electricity consumption, which is the amount of electricity consumed

⁴¹ AGEB (2015).
⁴² AGEB (2017a).

domestically, including grid losses and internal consumption, increased by 8 % or 44 TWh.⁴³

Electricity consumption at the final energy level has increased in three out of four sectors since 1990, rising most in the trade, commerce and services sector at 28 %, followed by private households at 10 % and industry at 8 %. In contrast, the transport sector experienced a 17 % decrease.⁴⁴

In terms of the absolute shares of the sectors, industry consumes the most electricity (46 %), followed by the trade, commerce and services sector (27 %), private households (25 %) and transport (2 %).

The shares of the energy sources used for gross electricity generation have changed considerably since 1990. Most noteworthy is the increase in the use of renewables to generate electricity from 3.2 % to 29 % and the decline of the fossil fuels lignite, coal, natural gas and heating oil along with nuclear energy from a total of almost 93 % in 1990 to 67 % in 2016. The use of natural gas to generate electricity nearly doubled during the same period. More electricity (123.5 TWh) was generated from renewables than from nuclear power for the first time in 2011.⁴⁵ A total of 188.3 TWh of electricity was generated from renewable energy sources in 2016, slightly more than in 2015.⁴⁶

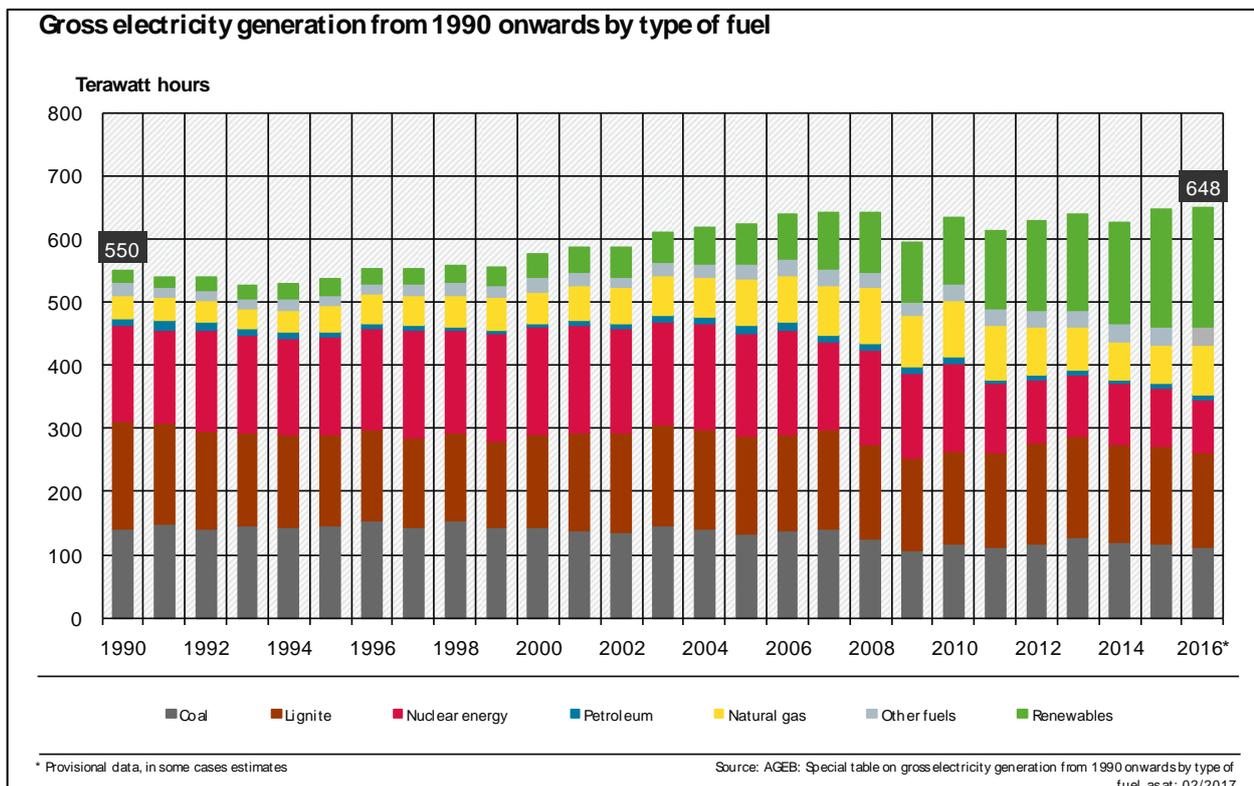


Figure 9: Gross electricity generation from 1990 onwards by energy source⁴⁷

Onshore wind energy contributed the most to renewable electricity generation in 2016, at 34.5 % or 65 TWh, followed by biomass (biogenic solid and liquid fuels; biogas, sewage gas, and landfill gas; and the biogenic portion of waste), which together accounted for

⁴³ AGEb (2017a).

⁴⁴ AGEb (2016).

⁴⁵ AGEb (2013).

⁴⁶ AGEe-Stat (2017).

⁴⁷ AGEb: Special table on grosselectricity from 1990 onwards by type of fuel, as at 02/2017.

27.4 % or 51.6 TWh of gross electricity generation. The decline in the expansion of photovoltaics that has occurred in recent years was reversed for the first time in 2016. New installed capacity of 1,476 MW slightly exceeded the previous year's level, although this was well below the upper limit of the expansion corridor of 2,400-2,600 MW specified in the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG).

Inputs of these energy sources to generate electricity between 1990 and 2015 declined overall by 8 %, even as gross electricity generation increased. The reason is that the average efficiency of power plants has improved, which in turn means that these energy sources are used more efficiently. The overall average gross efficiency of Germany's fossil power plants improved from 36.8 to 43.2 % between 1990 and 2015.⁴⁸ This trend reflects the ongoing modernisation of its power plants.

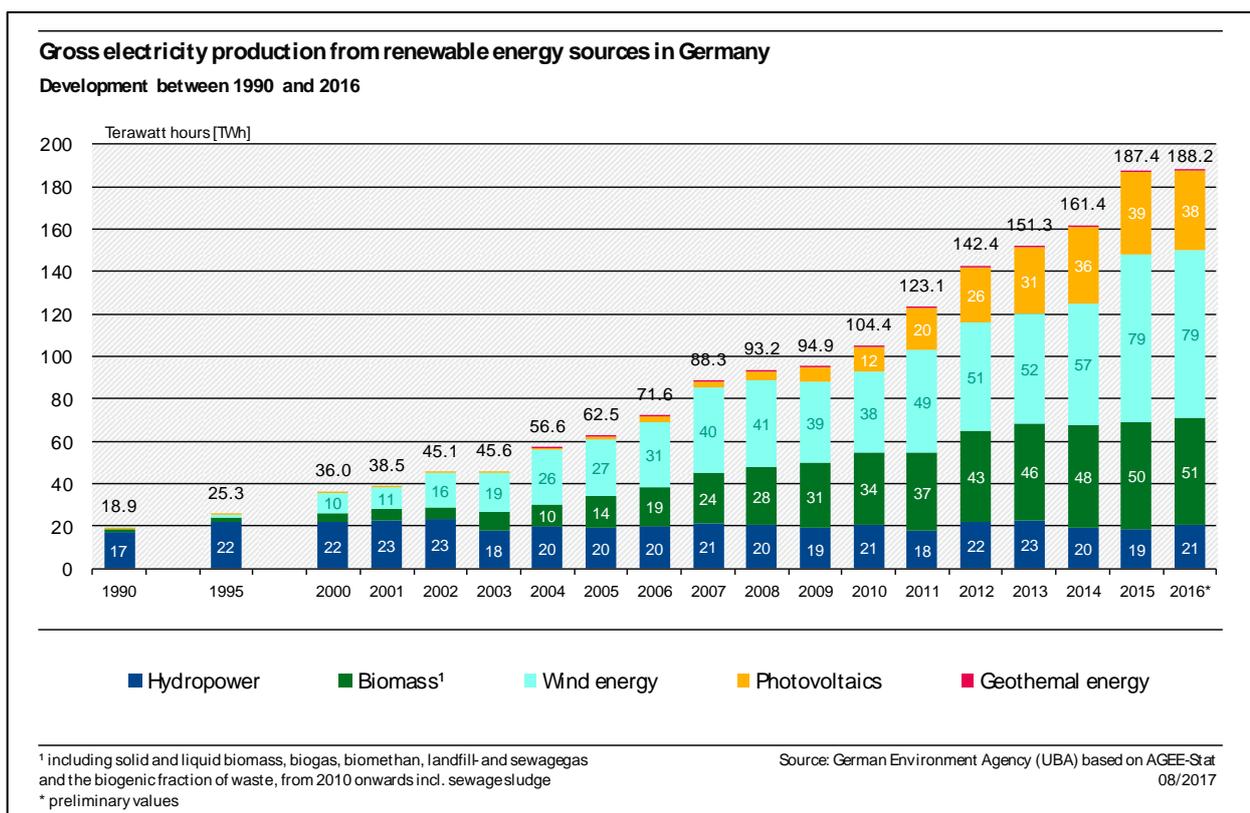


Figure 10: Electricity generation from renewable energy sources, 1990 to 2016 (in GWh)⁴⁹

2.6.4 Energy prices

Energy costs for consumers have been rising in recent years (as of 2015), both in absolute terms and as a share of household income or value added by trade and industry. The share of energy costs in gross value added to the economy has increased. Nonetheless, the competitiveness of the overall energy supply has been ensured, even if affordable energy remains a challenge for certain household groups. This applies particularly to households with relatively low incomes. The price of electricity is higher in Germany than in other countries in Europe and the rest of the world, although Germany is in the midrange among

⁴⁸ See Federal Environment Agency, authors' calculations based on AGE (2016) and AGE (2017), <https://www.umweltbundesamt.de/daten/energiebereitstellung-verbrauch/konventionelle-kraftwerke-erneuerbare-energien#textpart-5>.

⁴⁹ UBA (2017) based on AGEE-Stat.

EU Member States for the prices paid by particularly energy-intensive companies due to various types of relief that are offered.⁵⁰

Energy raw materials and emissions allowances

The prices of the energy resources oil, natural gas, and coal have increased since the turn of the century, due among other things to increased international demand. Prices fell by more than 30 % for a short time after the world economic crisis in 2008 and then rose sharply up to 2012. However, the prices of all major energy resources have experienced a downward trend since that time.

The situation in 2015 was as follows: the OPEC Basket Price per barrel of oil continued to decrease, averaging USD 49.52/bbl in 2015. The German border price for natural gas rose to EUR 5,618/terajoule (TJ) between 2014 and 2015. The price of importing coal into Germany declined to EUR 72.74/tonne of coal equivalent (tce) due to lower world demand.

A clear downward trend can still be observed for the prices of EU emissions allowances (EEX spot market) due to a surplus of allowances. The annual average price for 2015 was EUR 7.8/tonne CO₂, which is EUR 15/tonne CO₂ lower than in 2008.

These European and international price trends are important drivers of energy price and cost trends for end consumers in Germany.

Electricity

Prices on the European Electricity Exchange in Leipzig fell markedly in 2015, continuing the trend that began in 2011. The exchange price for electricity to be delivered the next year (baseload year-ahead) averaged EUR 31/MWh in 2015.⁵¹ Changes in the wholesale price affect the prices paid by end consumers, subject to a time lag.

Residential electricity prices were 29.11 euro cents/kWh in 2015 and rose 0.69 euro cents/kWh to 29.80 euro cents/kWh in 2016 (for consumption of 325 kWh/month, including taxes and surcharges, as of 1 April). Over the past few years, the main influence on the electricity prices paid by residential customers has been rising price components imposed by the government. Commercial and industrial customers that are not eligible for exemptions experienced trends for taxes, charges, and other price components imposed by the government which were similar to those for households.

⁵⁰ Federal Ministry for Economic Affairs and Energy (2016a).

⁵¹ Federal Ministry for Economic Affairs and Energy (2016a).

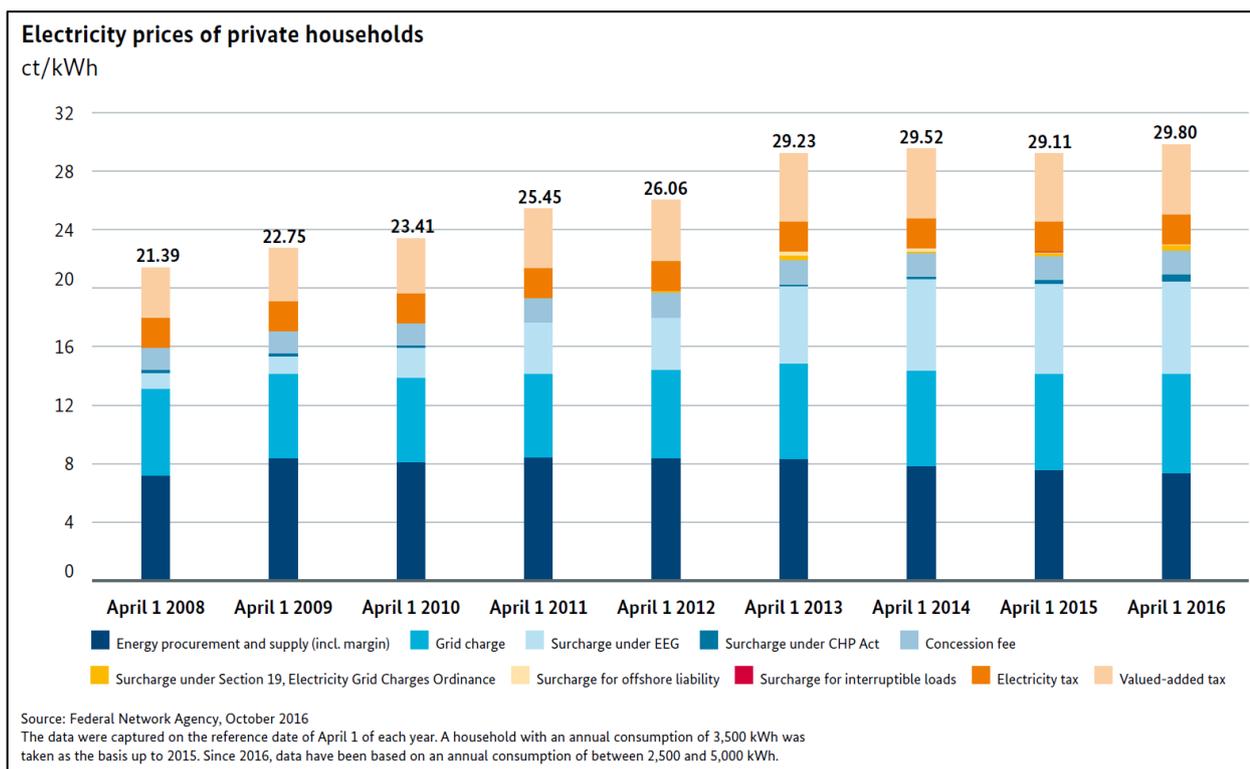


Figure 11: Electricity price for residential customers⁵²

The Bundesnetzagentur (Federal Network Agency) reports that large-scale customers that are not eligible for relief and consume 24 GWh/year fell within a range of 12.91-15.69 euro cents/kWh in 2016, while relief could lead to a reduction of up to 9.88 euro cents/kWh for the same consumption profile.⁵³

The electricity prices for customers in trade and industry do not apply to companies that are intensive users of electricity. Large electricity consumers may benefit from different types of relief under the Electricity Tax Act (Stromsteuergesetz) or Renewable Energy Sources Act if they fulfil the relevant criteria. Accordingly, electricity prices may be lower for some of those customers. However, there are no statistical surveys for this consumer segment, and the actual prices vary considerably.

In macroeconomic terms, energy spending aggregated over all end consumers has decreased since 2012. A total of EUR 90.1 billion was spent on the provision of primary energy in 2015, down about 20 % from the previous year. This was primarily due to a sharp decrease in the price of imported fossil fuels. Spending by final consumers on final energy consumption decreased 4 % from the previous year to EUR 215 billion in 2015.⁵⁴

2.6.5 Effects on greenhouse gas emissions

Energy-related emissions were primarily responsible for greenhouse gas emissions in 2015, with an 85 % share.⁵⁵ Energy-related emissions refers to emissions of greenhouse gases and air pollutants that are released by converting energy sources into electrical or thermal

⁵² Federal Ministry of Economic Affairs and Energy (2016a): Energy of the Future. Fifth Monitoring Report on the Energy Transition (12/2016 version), based on Bundesnetzagentur (Federal Network Agency).

⁵³ See Bundesnetzagentur, Bundeskartellamt (2016).

⁵⁴ See Federal Ministry of Economic Affairs and Energy (2016a), page 87.

⁵⁵ Federal Environment Agency (2016).

energy (electricity and heat production). Energy-related emissions are produced when generating electricity and heat in power plants. In the industrial sector, they are produced by certain industrial processes. In the household and small-scale consumer sector, energy-related emissions primarily result from using fossil fuels for heating. In the transport sector, they come from the exhaust of internal combustion engines. Fugitive emissions from agriculture or abandoned landfills or mines are not included among energy-related emissions.

Energy-related emissions of direct and indirect greenhouse gases are primarily influenced by the economic situation in an industrialised country such as Germany. Such emissions are strongly dependent on the mix of energy sources that is used, the efficiency of vehicles run on fossil fuels and how they are driven, the efficiency of other technologies that are used, and – given the need for heating – weather conditions.

2.7 Transport

2.7.1 Transport volumes

The trend for transport since 1991 is characterised by a moderate increase in passenger transport (measured in terms of billions of passenger kilometres, Table 1) and obvious growth in goods transport (measured in terms of tonne kilometres, Table 2). Passenger transport increased 34.8 % between 1991 and 2015. Private motor transport increased 32.7 %, remaining in the dominant position. Its share in total passenger transport fell only slightly, from 81.6 % to 80.3 %. Air transport grew faster than any other type of passenger transport. Passenger transport by air via Germany increased 171.2 % from 1991 to 2015. As a result, its share in all passenger transport rose from 2.6 % to 5.2 %.

Public road passenger transport declined by 2.5 % from 1991 to 2015, but there has been a slight upward trend since 2012. Its share in total passenger transport declined as a result from 9.3 % to 6.7 %, although there has been a slight upward trend since 2012. Passenger transport by rail increased dramatically by 60.1 %. Its share in total passenger transport therefore rose from 6.5 % in 1991 to 7.7 % in 2015. Overall, the shares of passenger transport by road and by rail, which on the whole are less energy-intensive, remained between 14 % and 16 % during the period under consideration.

Jahr	Eisenbahnen	%	ÖSPV	%	Luftverkehr	%	MIV	%	Gesamt
1991	57,0	6,5%	81,6	9,3%	22,6	2,6%	713,5	81,6%	874,7
1995	71,0	7,0%	77,0	7,6%	32,5	3,2%	830,5	82,2%	1011,0
2000	75,4	7,2%	77,3	7,4%	42,7	4,1%	849,6	81,3%	1045,1
2005	76,8	7,1%	82,5	7,6%	52,6	4,8%	875,7	80,5%	1087,6
2006	79,0	7,2%	81,8	7,4%	55,6	5,1%	882,6	80,3%	1099,0
2007	79,1	7,2%	81,3	7,4%	58,8	5,3%	883,4	80,1%	1102,6
2008	82,5	7,4%	79,6	7,2%	60,8	5,5%	888,5	79,9%	1111,4
2009	82,3	7,4%	78,6	7,0%	58,4	5,2%	898,7	80,4%	1117,9
2010	83,9	7,5%	78,1	7,0%	52,8	4,7%	902,4	80,8%	1117,2
2011	85,4	7,6%	78,0	6,9%	55,2	4,9%	912,4	80,7%	1131,0
2012	88,8	7,8%	76,0	6,7%	56,2	4,9%	914,6	80,5%	1135,6
2013	89,6	7,8%	77,1	6,7%	56,3	4,9%	921,4	80,5%	1144,5
2014	91,0	7,8%	78,8	6,8%	58,8	5,1%	935,0	80,4%	1163,5
2015	91,3	7,7%	79,5	6,7%	61,3	5,2%	947,1	80,3%	1179,2
2030	100,1	7,9%	82,8	6,6%	87,0	6,9%	991,8	78,6%	1261,7

Table 2: Motorised passenger transport in Germany, in billions of passenger kilometres (1991-2015, forecast for 2030)⁵⁶

Goods transport increased continuously from 1991 to 2008 to over 654.3 billion tonne kilometres (tkm) and then decreased by more than 10 % in 2009 due to the economic trend. However, in 2015 goods transport returned to the 2008 level following the economic recovery.

Goods transport increased by 62.5 % during the entire period (1991-2015). Air transport, which more than tripled, experienced the greatest growth, although this started from a very low level.

Road transport increased by 86.8 % during the same period. The share of goods transported by road therefore increased from 61.4 % in 1991 to 70.6 % in 2015. This resulted in part from the increase in transit traffic in Germany – on which Germany has no influence under international treaties – due to the eastward expansion of the EU.

The share of the more energy-efficient rail and inland waterway transport fell from 34.6 % to 26.4 % between 1991 and 2015.

⁵⁶ Federal Ministry of Transport and Digital Infrastructure (2016), Federal Ministry of Transport and Digital Infrastructure (2014).

Jahr	Eisenbahnen	%	Binnenschiff	%	Straße	%	Rohrfernleitungen	%	Luftverkehr	%	Gesamt
1991	82,2	20,6%	56,0	14,0%	245,7	61,4%	15,7	3,9%	0,4	0,1%	400,0
1995	70,5	16,3%	64,0	14,8%	279,7	64,9%	16,6	3,8%	0,5	0,1%	431,3
2000	82,7	16,2%	66,5	13,0%	346,3	67,7%	15,0	2,9%	0,8	0,1%	511,3
2005	95,4	16,5%	64,1	11,1%	402,7	69,4%	16,7	2,9%	1,0	0,2%	580,0
2006	107,0	17,2%	64,0	10,3%	435,7	69,9%	15,8	2,5%	1,2	0,2%	623,7
2007	114,6	17,6%	64,7	9,9%	454,1	69,8%	15,8	2,4%	1,2	0,2%	650,5
2008	115,7	17,7%	64,1	9,8%	457,6	69,9%	15,7	2,4%	1,4	0,2%	654,3
2009	95,8	16,4%	55,5	9,5%	415,6	71,1%	15,9	2,7%	1,3	0,2%	584,2
2010	107,3	17,1%	62,3	9,9%	440,6	70,2%	16,3	2,6%	1,4	0,2%	627,9
2011	113,3	18,0%	55,0	8,8%	442,6	70,5%	15,6	2,5%	1,5	0,2%	628,1
2012	110,1	17,8%	58,5	9,5%	432,0	69,9%	16,2	2,6%	1,4	0,2%	618,2
2013	112,6	17,7%	60,1	9,4%	443,7	69,8%	18,2	2,9%	1,4	0,2%	636,0
2014	112,6	17,5%	59,1	9,2%	451,9	70,3%	17,5	2,7%	1,4	0,2%	642,6
2015	116,6	17,9%	55,3	8,5%	459,0	70,6%	17,7	2,7%	1,4	0,2%	650,1
2030	153,7	18,4%	76,5	9,1%	607,4	72,5%	-	-	-	-	837,6

Table 3: Goods transport in Germany, in billions of tonne kilometres (1991-2015, forecast for 2030)⁵⁷

The Federal Ministry of Transport's transport interdependence forecast for 2030 assumes moderate growth in passenger transport and relatively strong growth in goods transport up to 2030. Road vehicles remain the dominant mode of transport.

2.7.2 Motor vehicle fleet

A total of 54.6 million vehicles were registered in the Federal Motor Transport Authority's (KBA) central registry on 1 January 2016, including 45.1 million passenger cars, 4.2 million motorcycles, and 3 million heavy goods vehicles and road tractors for semi-trailers. Including mopeds and other small motorcycles not subject to registration (2 million), and vehicle trailers (6.9 million), the total number of vehicles in Germany is 63.5 million.⁵⁸

Following a change to the KBA vehicle registry in 2008, vehicles whose registration has been temporarily cancelled are no longer included in the reported fleet. This means that data after 2008 is no longer comparable with data for 1991-2007 and must be analysed separately.

However, it is clear that the fleet of motor vehicles in Germany has increased constantly (see Table 3). It rose by 27.8 % from 1991 to 2007 and increased 10.3 % during the 2008-2016 period based on the new definition.

The number of passenger cars increased by 26.6 % from 1991 to 2007 and by another 9.4 % from 2008 to 2016. In 2016, 32.2 % of passenger cars had a diesel engine, while only 12 % did in 1991. Electric vehicles accounted for only 0.1 % of the fleet (25,502 vehicles). Some 8.1 % of cars (3.7 million) are off-road vehicles and SUVs. Their share has increased faster than that of other cars in recent years (4.8 % from 2.1 million in 2012).

The number of heavy goods vehicles increased much faster than the number of passenger cars: by 55.6 % from 1991 to 2007 and by 19.7 % during the 2008-2016 period. Due to their powerful engines and the long distances they travel, heavy goods vehicles are responsible for a disproportionate amount of the greenhouse gas emissions caused by motor vehicles.

⁵⁷ Federal Ministry of Transport and Digital Infrastructure (2016), Federal Ministry of Transport and Digital Infrastructure (2014).

⁵⁸ Federal Ministry of Transport and Digital Infrastructure (2016).

The fleet of two-wheeled motorcycles also increased considerably (1991-2007: 58 %; 2008-2016: 12.6 %).

Jahr	Pkw und Kombi	Motorisierte Zweiräder ¹	Lkw und Sattelzugmaschinen	übrige Kraftfahrzeuge	Gesamt (ohne Anhänger)
1991	36.772	3.734	1.760	2.595	44.861
1995	40.404	3.935	2.339	2.475	49.153
1999	42.324	4.925	2.619	2.489	52.356
2000	42.840	5.081	2.689	2.498	53.107
2005	45.376	5.614	2.758	2.559	56.305
2006	46.090	5.721	2.765	2.152	56.728
2007	46.570	5.899	2.804	2.168	57.442
2008 ²	41.184	5.550	2.503	2.077	51.314
2009	41.321	5.852	2.524	2.099	51.796
2010	41.738	5.867	2.556	2.128	52.289
2011	42.302	5.871	2.619	2.153	52.945
2012	42.928	6.004	2.713	2.186	53.831
2013	43.431	6.072	2.761	2.216	54.480
2014	43.851	6.099	2.814	2.247	55.011
2015	44.403	6.182	2.890	2.277	55.752
2016	45.071	6.249	2.995	2.308	56.623
(1) Krafräder, Mopeds, Mofas und Mokicks					
(2) ab 2008 ohne vorübergehend abgemeldete Fahrzeuge					

Table 4: Vehicle fleet in thousands⁵⁹

2.7.3 Sales of fuel

Sales of fuel (all liquid and gaseous fossil fuels and biofuel) for the entire transport sector (not including maritime shipping) increased 7.9 % during the 1991-2015 period. Trends differed for land-based and air transport.⁶⁰

Absolute fuel consumption for land-based transport⁶¹ remained stable from 1991 to 2015 (+ 0.9 %). Decreases in the specific fuel consumption of motor vehicles have been partially offset by growing transport volumes – particularly road transport of goods – and by a trend toward larger and more powerful vehicles.

The trends for sales of different types of fuel vary greatly. Sales of diesel fuel increased by 72.8 % from 1991 to 2016, while petrol sales declined sharply, by 44 %. Biofuels' share in road transport fuel in Germany in 2015 was around 5.0 %. In contrast to the trend for fuels used for road, rail and inland waterway transport, consumption of aviation fuel (kerosene) increased considerably, by 88.6 %, from 1991 to 2015.

2.7.4 Effects on greenhouse gas emissions

The trend for greenhouse gas emissions by the transport sector (Table 4) is to a great extent determined by the trend for emissions by road transport. In the classification used by

⁵⁹ Federal Ministry of Transport and Digital Infrastructure (2016).

⁶⁰ Ibid.

⁶¹ Road traffic, rail traffic, and inland waterways; does not include aviation.

the UN Framework Convention on Climate Change, road transport is responsible for more than 95 % of greenhouse gas emissions by transport, because air transport includes only national aviation and shipping includes only inland waterways. The international components of air transport and shipping are recorded for purposes of information only. Emissions from the provision of electric energy (indirect emissions) are not included in the transport sector, but this must be taken into account in light of the increasing electrification of road transport.

Greenhouse gas emissions from road transport decreased by over 2 % between 1991 and 2015. Those emissions had risen between 1991 and 1999 and have risen since 2009, but they declined during the 1999-2009 period. Given the high percentage of emissions from road transport, this trend is also reflected in the greenhouse gas emissions of the entire transport sector.

The conversion of the railways from diesel to electric traction and technical and operational improvements in efficiency led to much greater reductions in emissions than was the case for road transport. Greenhouse gas emissions by rail transport declined by 64.5 % from 1991 to 2015.

Emissions from inland waterway transport decreased considerably, 49.3 %, during the 1991-2015 period, although less than in the rail transport sector. The cause was improvements in efficiency and increased refuelling in other countries.

Overall, therefore, transport (not including international aviation and maritime shipping) was responsible for emissions of about 159.6 Mt CO₂e in 2015, 4 % less than during base year 1991, in spite of a considerable increase in the overall volume of transport during the same period. The reason for this is more efficient vehicles. Transport accounted for 18 % of all greenhouse gas emissions in 2015.

Jahr	Straße	Schiene	Binnenschiff	Nationaler Flugverkehr	Summe	Internationaler Flugverkehr ¹
1991	157.825	2.597	3.451	2.354	166.227	11.841
1995	168.846	2.339	2.878	2.454	176.517	14.894
2000	174.507	1.956	2.088	2.784	181.335	19.283
2005	153.993	1.371	1.968	2.549	159.881	22.932
2006	149.928	1.294	1.829	2.615	155.666	24.150
2007	146.951	1.266	1.889	2.670	152.776	25.068
2008	146.747	1.245	1.868	2.708	152.570	25.321
2009	146.495	1.095	1.781	2.589	151.960	24.615
2010	147.624	1.116	1.703	2.576	153.018	24.222
2011	149.639	1.126	1.749	2.609	155.124	23.035
2012	148.360	1.037	1.761	2.450	153.608	24.998
2013	152.698	1.055	1.774	2.212	157.740	25.535
2014	153.852	944	1.885	2.233	158.914	24.566
2015	154.590	922	1.816	2.239	159.567	24.550
(1) nachrichtlich						

Table 5: Trend for greenhouse gas emissions in the transport sector in 1,000 tonnes CO₂e (1991-2015)⁶²

⁶² UBA (2017c).

2.8 Industry

2.8.1 Structure

The automotive and mechanical engineering industries play a leading role in Germany in terms of revenue and the number of jobs. Other major industries are metal and chemicals, as well as the food industry (see Figures 12 and 13). According to the Federal Statistical Office, the manufacturing industry's share in gross value added in Germany has remained relatively constant at 22-23 % since 2000, twice as high as in France, for example.⁶³ It was as much as 36.5 % in 1970. German industry is distinguished by its sectoral specialisation, including regional clusters of efficient SMEs, large companies and research institutions, and by the availability of highly qualified skilled workers and engineers.

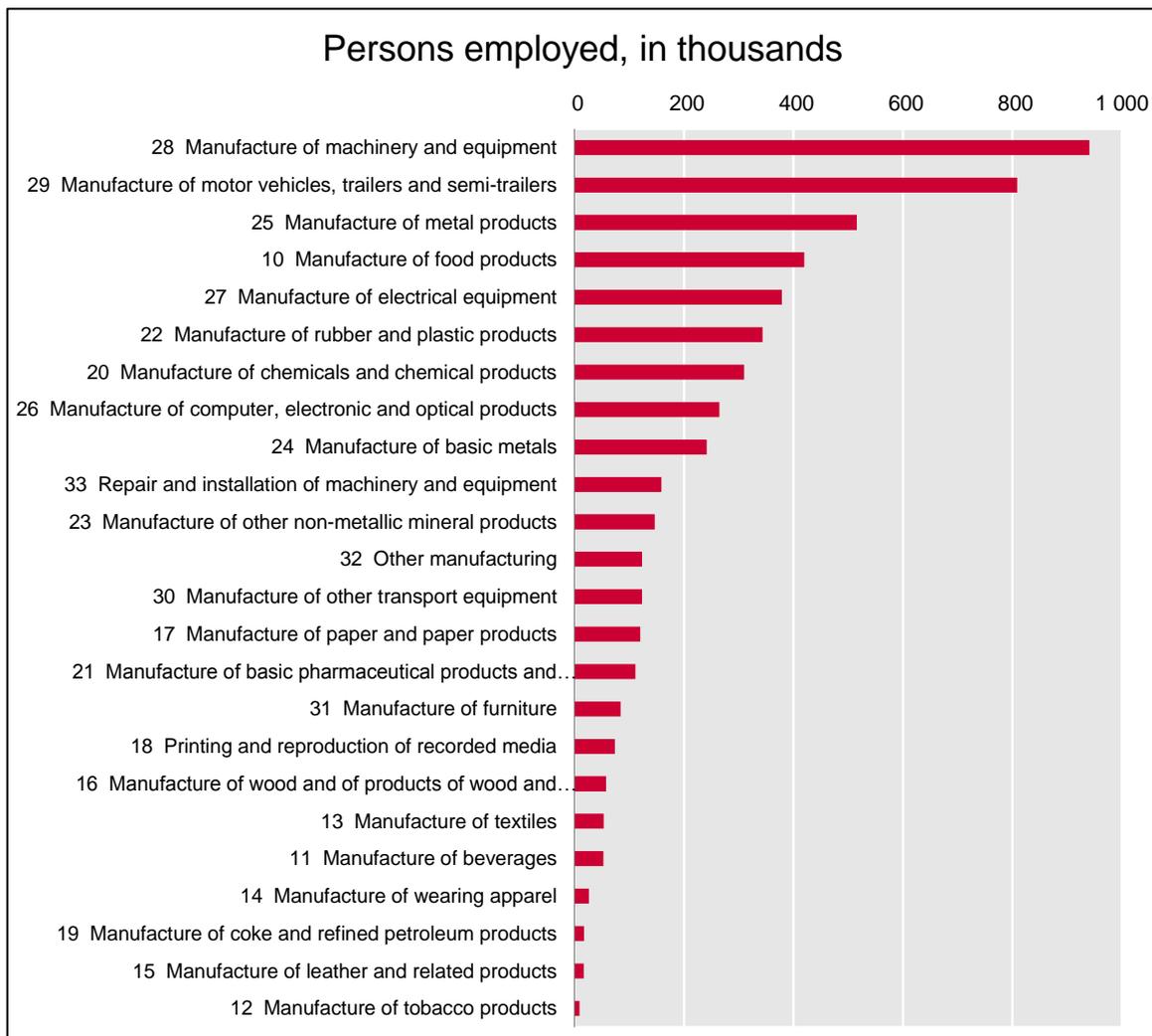


Figure 12: Number of people employed in industry and the manufacturing sector in 2016, companies with more than 50 employees⁶⁴

⁶³ Federal Statistical Office (2017e).

⁶⁴ Federal Statistical Office (2017f).

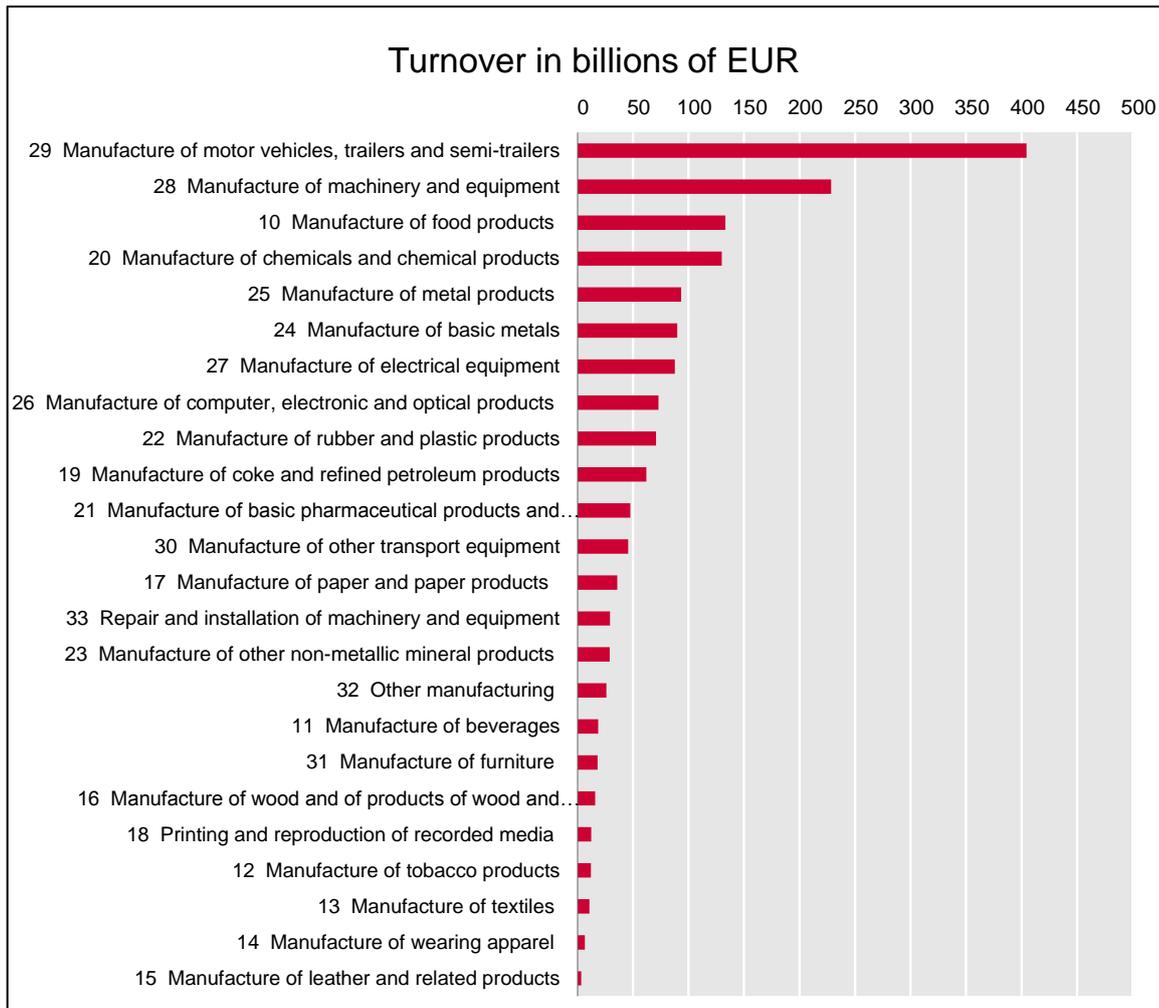


Figure 13: Revenue in industry and the manufacturing sector in 2016, companies with more than 50 employees⁶⁵

Industrial companies based in Germany have often focused on high-quality specialised and niche products such as technical textiles and special steels. Their relatively high expenditure on research and development enables them to maintain their leading positions in many areas.

The need to combat climate change poses major technical and economic challenges for German industry but it also offers opportunities. German industry – particularly the fields of mechanical engineering, plant construction, measurement and control technology and electrotechnology – is a leader in the export of products related to environmental and climate protection.

2.8.2 Effects on greenhouse gas emissions

Industry's share in total final energy consumption has fallen since 1990: it consumed only 29 % of total final energy in 2015 (1990: 31 %, see Figure 7).

Process-related emissions by industry are strongly linked to production levels. CO₂ emissions are particularly indicative of the economic trend for the mineral, chemicals and metal manufacturing industries. Efforts by manufacturers to reduce emissions from the

⁶⁵ Federal Statistical Office (2017g).

production of adipic acid in 1997 and 2010 considerably reduced N₂O emissions in this sector.

A combined 36.3 % reduction in greenhouse gas equivalents has been achieved for all industrial processes and product applications since 1990. Since then, the level of emissions has remained stable.

2.9 Waste management and wastewater treatment

2.9.1 Waste generation

Germany generated 51.1 million tonnes of municipal waste in 2014.⁶⁶ Municipal waste includes household waste, commercial waste similar to household waste and bulky waste, as well as various recoverables such as used paper, used glass, biowaste, garden waste and packaging which can be recycled using many different processes. The recovery rate for all municipal waste in 2014 was 88 %, up 18 % from 2006. The recycling rate for 2014 was 66 %.

In addition to municipal waste, other types of waste were produced in the following quantities in 2014: 30.2 million tonnes of waste from extracting and processing natural resources, 209.5 million tonnes of construction and demolition waste, 59.51 million tonnes of other waste (particularly manufacturing and commercial waste), and 50.6 million tonnes of waste from waste treatment facilities (see Figure 14).

⁶⁶ Federal Statistical Office (2016b).

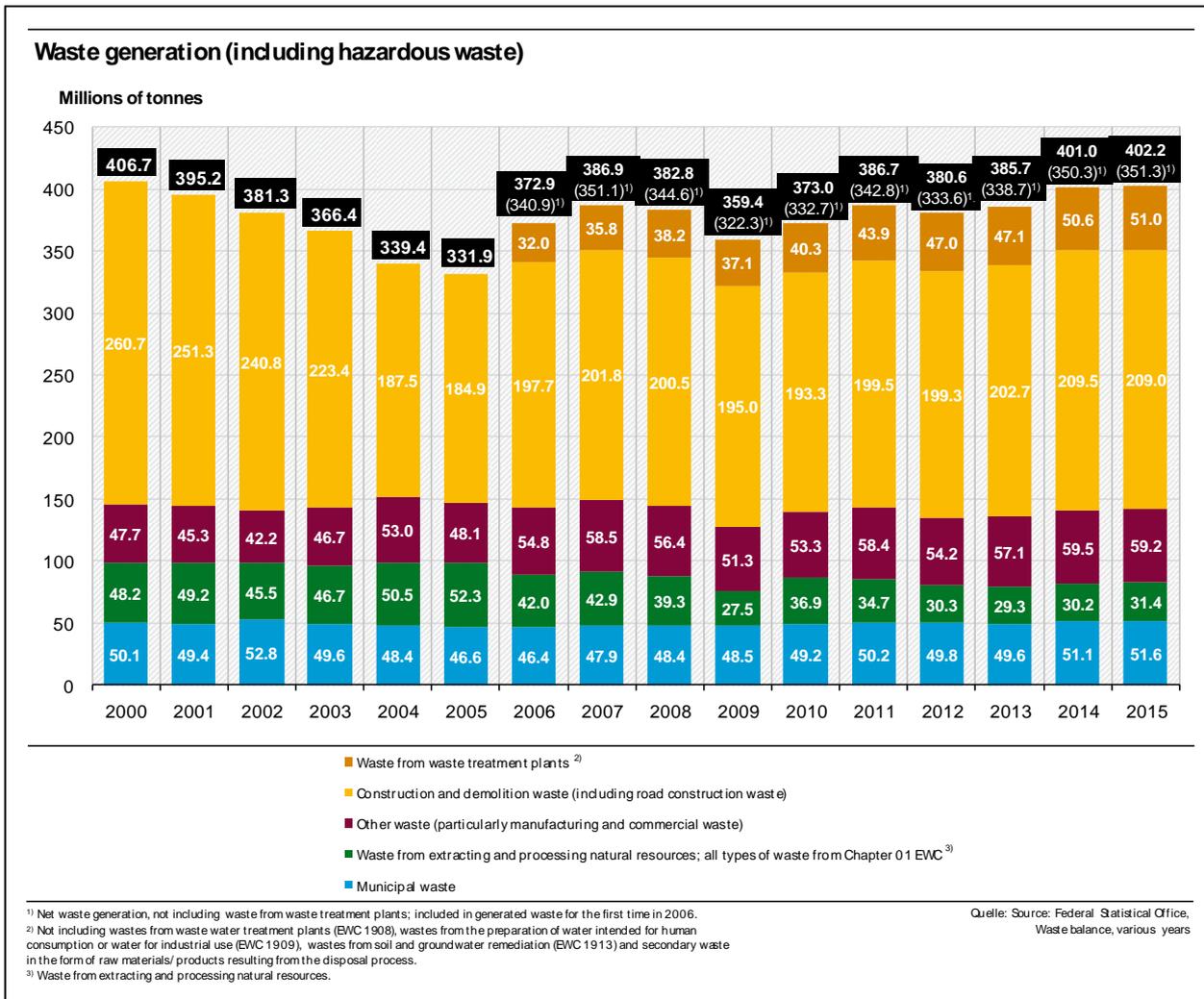


Figure 14: Waste generation in Germany 2000-2014⁶⁷

A total of 401 million tonnes of waste was generated in 2014 (350.3 million tonnes minus double counting due to waste from waste treatment facilities). The recovery rate was 79 %, and the recycling rate was 69 %. No more than 18 % of this waste is sent to landfills.

2.9.2 Legal basis and objectives of waste management

The fundamental legislation governing waste management is the Circular Economy Act (Kreislaufwirtschaftsgesetz) of 24 February 2012.⁶⁸ The Act specifies the following five-level hierarchy: avoidance, preparation for reuse, recycling, other recovery (particularly energy recovery and backfilling) and disposal. Various implementing regulations and laws obliging manufacturers to take back individual product groups or materials (such as packaging, electronic devices, batteries and used oil) have been adopted with the objective of preventing and recovering certain waste fractions. The Landfill Regulation (Deponieverordnung) of 27 April 2009⁶⁹ is very important for waste disposal. To avoid further emissions (landfill gas and polluted leachate) from landfills, it abolished the practice of sending untreated municipal waste to landfills starting on 1 June 2005. Sending

⁶⁷ Federal Statistical Office, Waste balance, various years

⁶⁸ Federal Law Gazette I, page 212.

⁶⁹ Federal Law Gazette I, page 900.

biodegradable waste and waste with a high calorific value to landfills was therefore prohibited from 1 June 2005; it must now go to waste incineration plants (WIPS) or mechanical biological treatment (MBT) plants.

2.9.3 Thermal treatment of waste and energy recovery

According to the Sixth National Communication, 70 incineration facilities for household waste with a total capacity of about 19 million tonnes per year and 30 RDF-fired power plants with capacity of about 4.5 million tonnes per year were operating in Germany in 2011. Approximately 0.9 million tonnes of RDF (refuse-derived fuel) were used in coal-fired power plants and about 2 million tonnes were used in the cement industry in 2011.

Reference is made to the Sixth National Communication because it is assumed that no material changes have occurred in this area over the past few years.

All waste incineration plants in Germany use the energy released by the waste. Most plants co-generate electricity and heat or produce steam for power plants or industrial operations. This replaces fossil fuels, thereby conserving fossil resources. It also avoids fossil CO₂ emissions, since residual waste on average contains about 50 % non-fossil organic components. In 2011, waste incineration plants produced 4,950 GWh of electricity and 7,600 GWh of heat from the biogenic portion of waste; this avoided a total of 6 Mt CO₂e and was climate-neutral.⁷⁰

To determine the present situation, the Federal Environmental Agency has commissioned an expert report to investigate the current status and the potential for generating energy from waste in Germany up to 2030.⁷¹

All plants in which waste undergoes thermal treatment are subject to the Incineration and Coincineration of Waste Regulation (Verordnung über die Verbrennung und Mitverbrennung von Abfällen) and must comply with strict emissions limits and operating parameters to protect the environment.

2.9.4 Biological mechanical waste treatment

Germany had 42 biological mechanical waste treatment plants with annual capacity of about 5.0 million tonnes in 2016. Some 2.5 million tonnes of municipal waste were also treated in 30 mechanical waste treatment plants. When treating a total of about 7.5 million tonnes of waste in the two types of plant, 4.5 million tonnes of high-calorific-value fractions were separated for use as RDF and 0.2 million tonnes of metals and 0.2 million tonnes of other recyclables were separated for recovery. Only about 1 million tonnes of waste that was pre-treated in these plants was sent to landfills. Biological mechanical waste treatment achieves a net reduction of 2.1 to 2.5 Mt CO₂e in the climate footprint (adjusted for its own energy consumption).⁷²

Biological mechanical waste treatment plants must fulfil the requirements of the Landfill Regulation (Deponieverordnung) and the Biological Waste Treatment Plants Regulation (Verordnung über Anlagen zur biologischen Behandlung von Abfällen) and the provisions of Annex 23 to the Wastewater Regulation (Abwasserverordnung). They ensure low-emission

⁷⁰ Federal Ministry of the Environment, Nature Conservation and Reactor Safety (2012a).

⁷¹ Federal Environment Agency: Energieerzeugung aus Abfällen – Stand und Potenziale in Deutschland bis 2030, project number 75778, project dates: 7 July 2016 to 7 August 2017.

⁷² Arbeitsgemeinschaft Stoffspezifische Abfallbehandlung (ASA) (2011).

waste treatment in biological mechanical waste treatment plants and environmentally compatible landfill practices for the treatment residue.

2.9.5 Recovery of biowaste and green waste

Germany separately collects and recovers biowaste and green waste, so it has established its recovery of biodegradable waste at a very high level compared with other countries. An average of 120 kg of biowaste and green waste per inhabitant was separately collected in 2014. Some 9.8 million tonnes of biowaste and green waste (such as biowaste from households, waste from gardens and parks, food waste from restaurants and waste from markets) is generated in local communities, and there is a rising trend.⁷³ There is still considerable potential for separate collection of more biowaste and green waste. Separate collection of biowaste and green waste that must be disposed of by a public waste management organisation has been mandatory since 1 January 2015.

The operation of almost 1,000 large composting plants (each with annual capacity of over 1,000 tonnes) meant that total capacity was over 10 million tonnes in Germany in 2014. Half of those plants process green waste only; the other half process biowaste and green waste.

There were also some 100 biowaste digestion plants in Germany in 2014 which used different methods, operating continuously or in batches, to digest and compost about 1.6 million tonnes of biowaste. Suitable biowaste will increasingly undergo digestion followed by composting. That will improve the use of biowaste to produce energy and allow recovery of the organic material and its components for use as soil conditioners. Depending on the quality of the input and the method used, each tonne of biowaste that is digested produces between 80 and 140 cubic metres (m³) of biogases with a methane content of 50 to 65 %. The energy it contains corresponds to 50 to 80m³ of natural gas.

The biogas is usually converted directly into electricity (200 to 300 kilowatt hours per tonne (kWh/t) input) and heat (also about 200 to 300 kWh/t input) in a combined heat and power plant (CHP). If 20,000 tonnes of biowaste were generated each year, a CHP plant with capacity of 600 kW (electric) could produce sufficient electricity for 1,000 to 1,500 households. It is also possible to improve the quality of biogas so that it is of the same quality as natural gas ("biomethane"). In addition to expanding separate biowaste collection, there are plans to optimise the recovery of biowaste. One way to do this is to use suitable green waste containing a high proportion of wood to produce heat.

2.9.6 Landfills

Sending waste containing large amounts of organic biodegradable material to landfills, which can contribute to the formation of methane and methane emissions, has been prohibited since 1 June 2005. Only about 110 former household waste landfills were still operational in 2011. According to the Landfill Regulation, only waste that contains less than 3 percent by weight total organic carbon (TOC) or does not contribute to gas formation may be sent to those landfills.

The other household waste landfills were shut down or upgraded to comply with statutory requirements. For the larger centralised landfills, this includes regular active landfill degasification with use of the energy. For smaller landfills with a low level of gas formation, oxidation of the methane usually takes place in the revegetation level.

⁷³ Federal Statistical Office (2017h).

No more biodegradable waste may be sent to landfills, and the biodegradation of the waste sent to landfills before 2005 is progressing, so methane emissions from landfills will continue to decrease from their current low level and then disappear over the next few years.

Year	1990	1993	1999	2003	2008	2011	2015
Number of (former) household waste landfills	8,273	562	376	302	130	110	N/A
Waste containing a high biodegradable fraction (millions of tonnes), such as household waste	43.3	27.8	15.5	11	0	0	0
Estimated methane emissions from landfills (millions of tonnes)	1.34	1.47	1.12	0.88	0.6	0.47	0.36

Table 6: Changes in quantities of biodegradable waste sent to landfills, including number of landfills and methane emissions⁷⁴

2.9.7 Effect on greenhouse gas emissions

Germany had a study done in 2008/2009 to determine the potential for climate change mitigation offered by waste management.⁷⁵ According to it, climate-damaging emissions from the waste management sector declined from some 56 Mt CO₂e in 1990 to about 38 Mt CO₂e at the end of 2006, which is a net reduction of around 18 Mt CO₂e. The aim is to achieve even more systematic recovery from all municipal waste by 2020 by further expanding separate collection and focusing on material recovery and by increasing the efficiency of recovery. Sending waste to landfills is to be avoided to the extent possible.

According to new calculations by the Federal Environmental Agency (UBA), taking into account the actual collection of landfill gas and residual gas emissions from existing landfill sites, methane emissions from landfills fell by around 75 %, from 1.33 million tonnes in 1990 to 0.36 million tonnes in 2015.⁷⁶ This is equivalent to a total reduction of 25 Mt CO₂e up to 2015.

Municipal waste incineration plants handle the largest quantities of residual municipal waste, approximately 19 million tonnes. In 2009 7.7 TWh of electrical energy was generated, and 14.2 TWh of heat was exported. Municipal waste incineration plants therefore achieved a net reduction in fossil CO₂ emissions of about 3.9 million tonnes,

⁷⁴ UBA (2017): National Inventory Report.

⁷⁵ ifeu (Institut für Energie- und Umweltforschung)/Öko-Institut (2010).

⁷⁶ Federal Environment Agency (2017c).

taking into account energy purchased from external sources and metal recovered from incineration residues. Current data about the amounts of energy generated from waste are being determined as part of an expert report (see Chapter 2.9.3).

Digestion of biowaste from households offers additional potential for reducing CO₂ emissions. Both ifeu and Öko-Institut estimate that improving biowaste recovery can save as much as 2 million tonnes CO₂e by 2020.

2.9.8 Municipal wastewater treatment

2.9.8.1 Municipal wastewater generation

In Germany, 96.2 % of the population is connected to public wastewater treatment plants.⁷⁷ Some 81 % of wastewater from the rest of the population is discharged into small treatment plants, and some 21 % into septic tanks. The 9,300 municipal sewage treatment plants handle about 10 billion m³ of municipal wastewater from homes and businesses. Half of the wastewater is used water and half is precipitation and infiltration water. In terms of population equivalents (PE), the wastewater has a load of approximately 117 million PE. One PE is equivalent to a chemical oxygen demand (COD) of 120 g. Approximately 1.1 billion m³ of wastewater is treated in industrial sewage treatment plants.

2.9.8.2 Greenhouse gas emissions from municipal wastewater treatment plants and small private treatment systems

Municipal wastewater treatment in Germany normally takes place under aerobic conditions (municipal wastewater treatment plants and small private treatment systems), i.e. methane emissions are very low. Open digestion for sludge stabilisation, which did cause methane emissions, was abolished in 1994. Sludge stabilisation using anaerobic digestion can be economical for municipal wastewater treatment plants above 50,000 PE; the methane that is produced is collected and used to produce energy. However, uncontrolled anaerobic processes can cause methane to be produced in the septic tanks of homes that are not connected to the public sewer system or to small treatment plants. A total of 574,600 people were still discharging wastewater into septic tanks in 2010.⁷⁸ However, the organic load discharged into septic tanks has been drastically reduced since 1990, resulting in a strong downward trend for methane emissions (from 180 kt/a in 1990 to 9.5 kt/a in 2015).⁷⁹

Nitrous oxide (N₂O) emissions can be a by-product of municipal wastewater treatment, particularly as a result of denitrification, during which gaseous end products (primarily molecular nitrogen) are produced from nitrate. The level of N₂O emissions in the wastewater sector depends on the per capita discharge of protein, so it is directly related to lifestyles and consumption patterns.

According to calculations done for the 2012 National Inventory Report,⁸⁰ 3,370 tonnes of methane (70,800 tonnes CO₂e) and 7,430 tonnes of nitrous oxide (2,303,300 tonnes CO₂e) were produced by municipal wastewater treatment plants in 2010, a total of almost 2.4 Mt CO₂e. Methane emissions from wastewater treatment have declined by 93.8 % since 1990, while nitrous oxide emissions have risen 3.6 %.

⁷⁷ Federal Statistical Office (2015c), data for 2013.

⁷⁸ Ibid, data for 2013.

⁷⁹ Federal Environment Agency (2017c).

⁸⁰ Federal Environment Agency (2012).

2.9.8.3 Energy consumption and electricity generation by municipal wastewater treatment plants

The energy consumption of municipal wastewater treatment plants decreased from 4,400 GWh per year to 4,200 GWh per year between 2005 and 2010. Electricity generation by wastewater treatment plants increased from 870 GWh per year in 2005 to 1,450 GWh per year in 2016. Approximately 92 % of the electricity that was generated was used by the plants for their own power supply.⁸¹ The version of the Water Management Act (Wasserhaushaltsgesetz) dated 5 December 2012 specifies that the energy efficiency of wastewater treatment plants is a criterion for establishing the state of the art.

2.10 Buildings sector – heating and cooling

2.10.1 Buildings-related energy consumption in 2015

Energy-consuming applications that are directly related to the use of buildings include space heating (heating systems), the provision of hot water, cooling (air conditioning), and interior lighting. The buildings-related final energy consumption by those applications totalled 853 TWh in 2015. This means that final energy consumption in the buildings sector was 106 TWh lower (11 %) than in 2008.

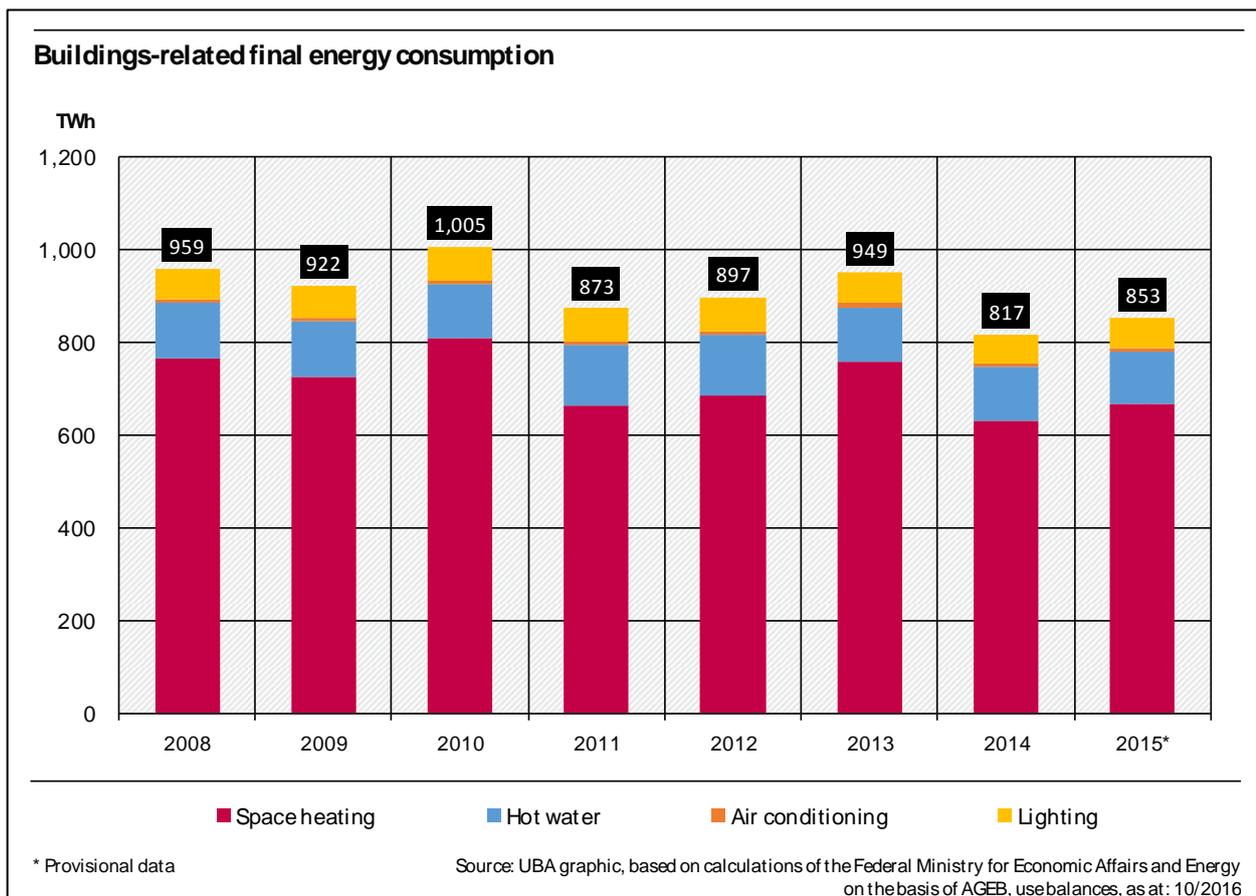


Figure 15: Buildings-related final energy consumption⁸²

⁸¹ Federal Statistical Office (2017i).

⁸² Federal Ministry of Economic Affairs and Energy (2016a) based on AGEB; UBA graphic.

Figure 15 shows that space heating was responsible for the majority of final energy consumption in the buildings sector in 2015. Final energy consumption for space heating is highly dependent on weather conditions and varies each year. Hot water's share in buildings-related final energy consumption was 13 % in 2015. Lighting accounted for 7 % of final energy consumption. Air conditioning was responsible for 1 % of final energy consumption in buildings. Final energy consumption for air conditioning jumped over 30 % between 2008 and 2015.

Renewables contributed 97 TWh to space heating and 14 TWh to hot water in 2015. Renewable energy's share has thus increased to 13 %. In 2008, renewables' share in buildings-related final energy consumption was 8 %.⁸³

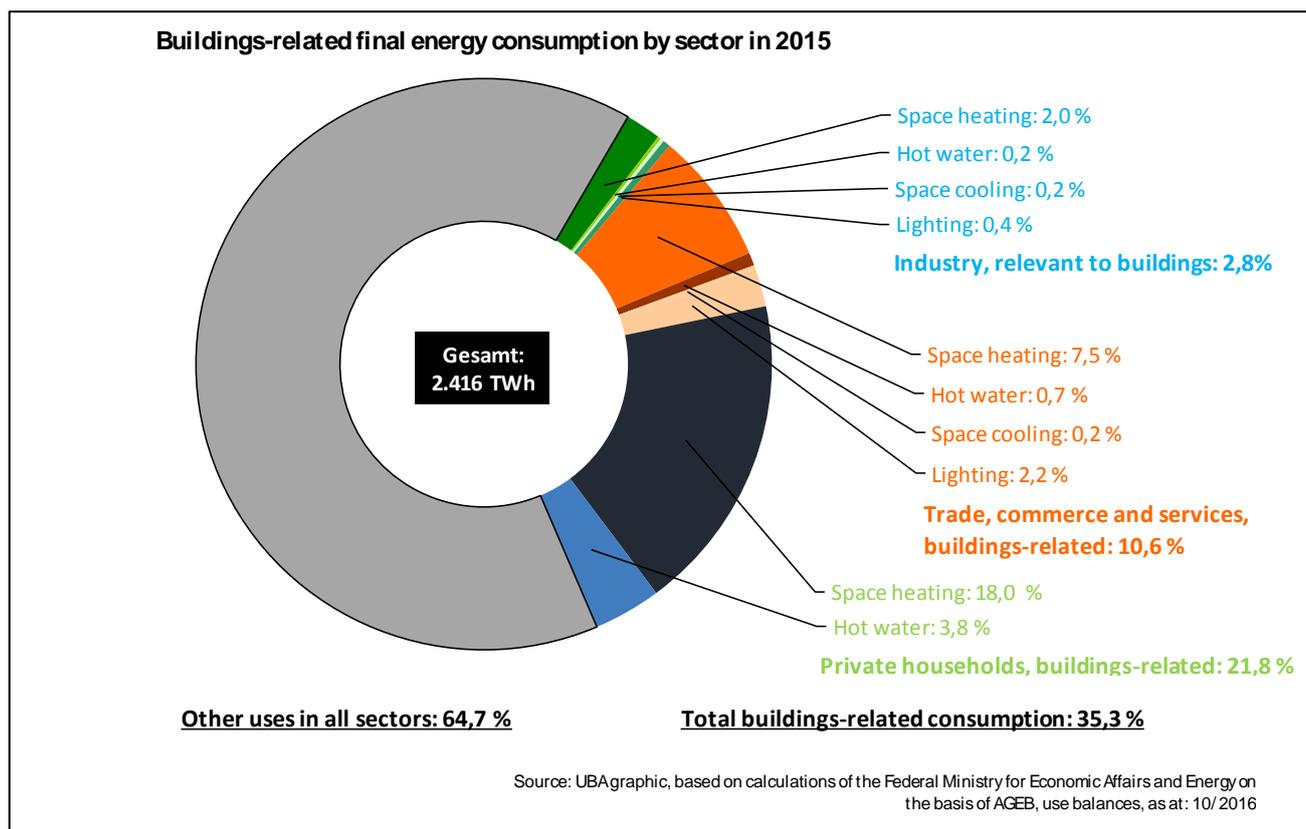


Figure 16: Buildings-related final energy consumption by sector⁸⁴

Figure 16 shows that space heating in private homes is extremely important for both buildings-related final energy consumption and final energy consumption in general. Reducing the heat demand of buildings is therefore a key element of Germany's energy transition. The target reduction of 11.1 % from 2008 levels was exceeded as the reduction reached 13 % in 2015. The aim is a 20 % reduction in heat demand by 2020 compared with 2008 levels. The target for renewables' share in total heat consumption is also a 14 % rise by 2020. Some 17 % of buildings-related heat consumption was already met by renewable energy sources in 2015.⁸⁵

⁸³ AGEb (2013) and (2016).

⁸⁴ Federal Ministry of Economic Affairs and Energy (2016a) based on AGEb; UBA graphic.

⁸⁵ Federal Ministry for Economic Affairs and Energy (2016a).

2.10.2 Energy efficiency in the building stock in the private household sector

Since space heating accounts for a major share of final energy consumption by homes, increasing the energy efficiency of the building stock is an important tool for the energy transition.

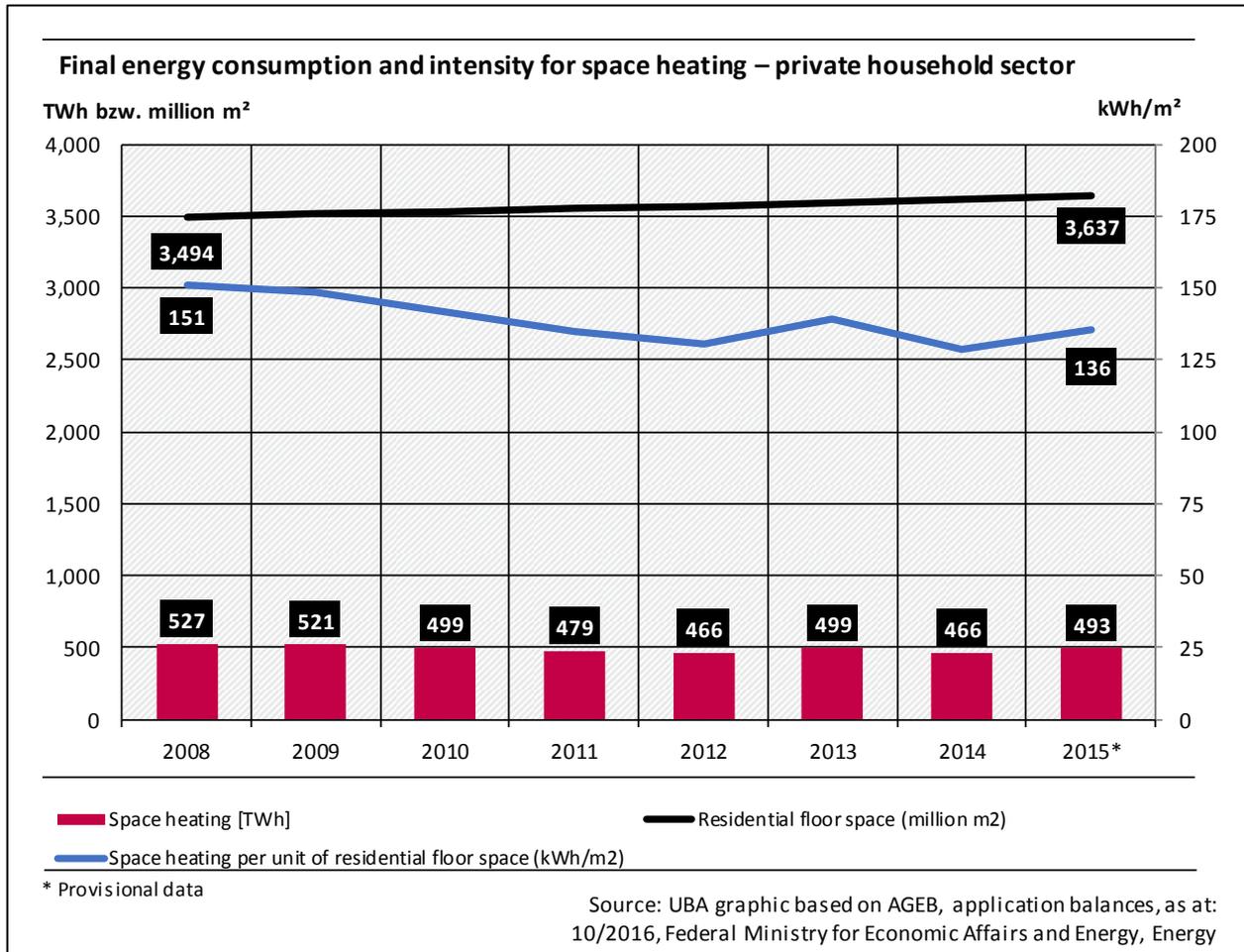


Figure 17: Final energy consumption and intensity for space heating – private household sector⁸⁶

Figure 17 shows the reduction in the demand for energy used for space heating in residential buildings in Germany. It was achieved in spite of the increase in residential floor space. Accordingly, the energy intensity of space heating fell from 151 kWh/m² to 136 kWh/m² between 2008 and 2015.

⁸⁶ Federal Ministry for Economic Affairs and Energy (2016a), UBA graphic.

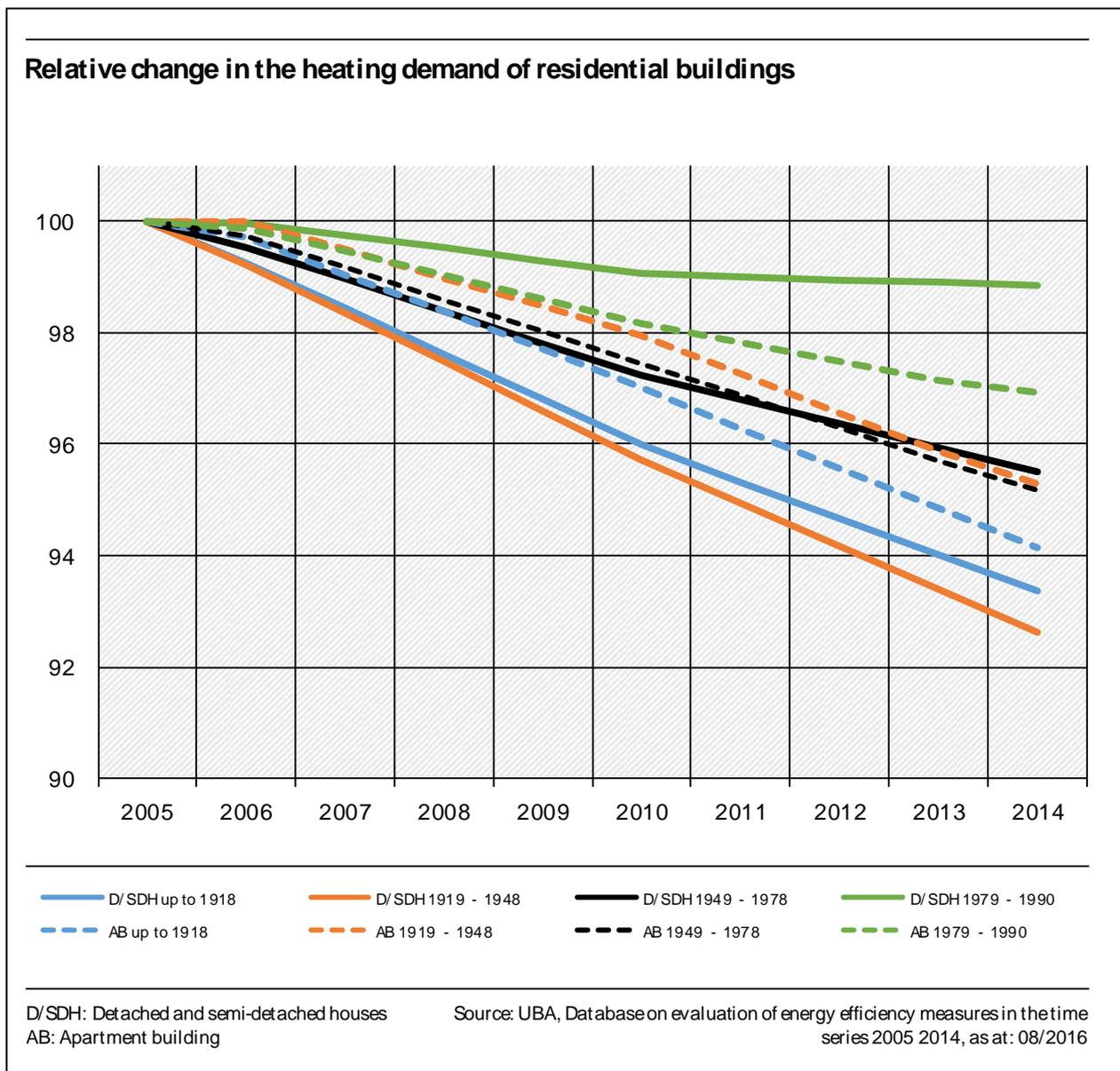


Figure 18: Change in the heating demand of older buildings (detached and semi-detached houses and apartment buildings)⁸⁷

Refurbishing buildings to make them more energy-efficient is the most important method for reducing space heating demand because more than two-thirds of housing in Germany was built before 1979. Figure 18 shows the relative trend in specific heating demand for detached and semi-detached houses and apartment buildings since 2005. The decrease in the amount of energy needed during the heating period to maintain the desired room temperature is particularly noteworthy for buildings constructed before 1979. It was not possible to improve the energy efficiency of buildings constructed after reunification to the same extent.⁸⁸

Buildings constructed since 2009 are an exception to that. Increased climate awareness and new construction methods have led to considerable reductions in the specific heating demand of new builds in a short time, as shown by Figure 19.

⁸⁷ UBA (2016).

⁸⁸ Federal Environment Agency (2016).

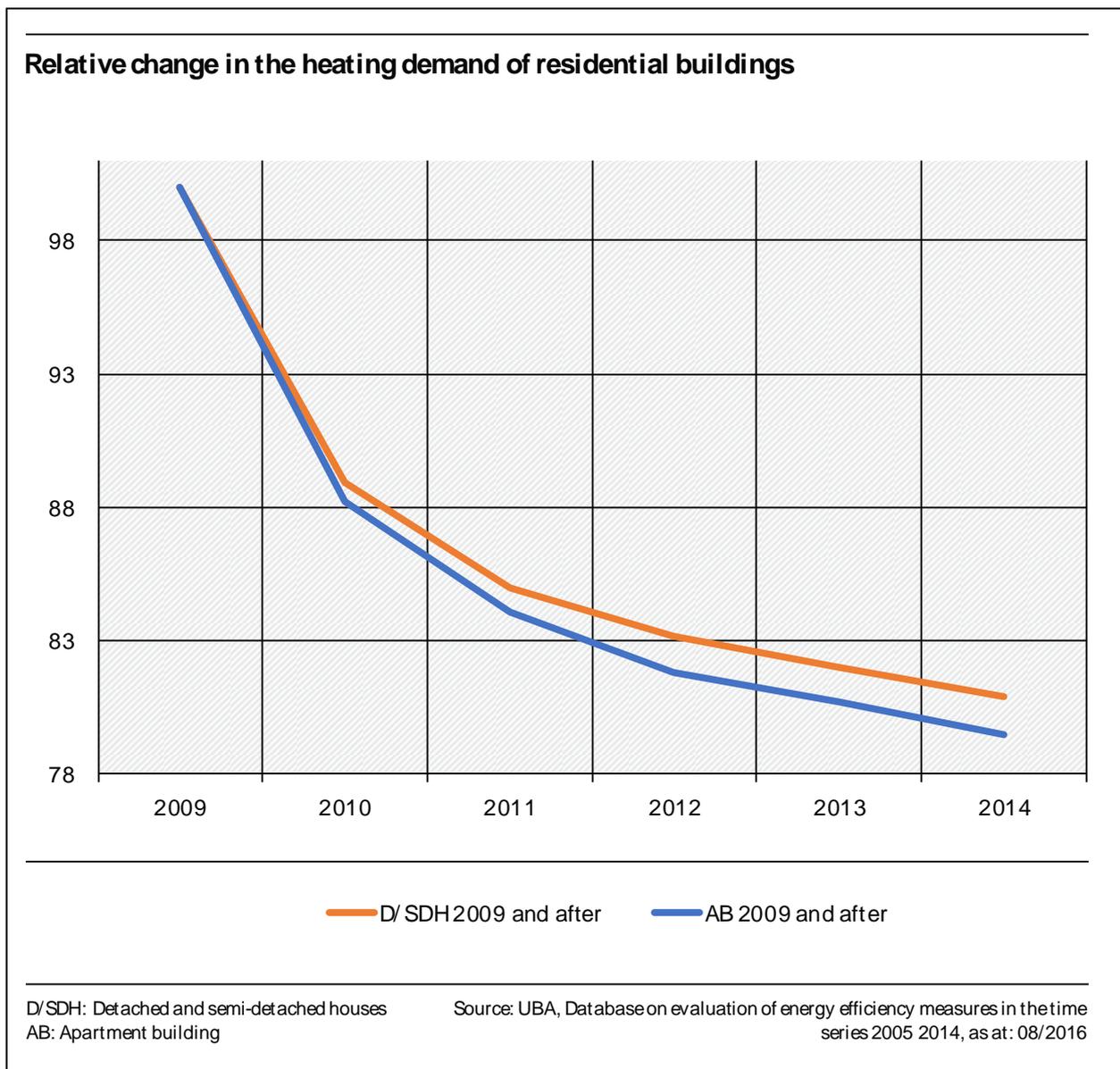


Figure 19: Changes in the heating demand of new builds (detached and semi-detached houses and apartment buildings)⁸⁹

In addition to energy-efficient building refurbishment, modern heating systems also help reduce the heating demand of private homes. Petroleum products and natural gas continue to dominate in the area of space heating. However, the share of renewables in the heating mix for the buildings sector rose from 4 % to 10 % during the 2005-2014 period.

Renewables' share in final energy consumption for heating was as high as 13.4 % in 2016.⁹⁰

Buildings-related final energy consumption accounts for a large share of total final energy consumption, so increasing energy efficiency in the buildings sector is an important instrument for achieving the aims of Germany's energy transition in that sector. Funding energy-efficient refurbishment programmes, advisory services on how to conserve energy in the home, incentive programmes for the expansion of renewables in the heating sector

⁸⁹ UBA (2016a).

⁹⁰ AGEE-Stat (2017).

and information campaigns are methods for increasing the energy efficiency of existing private homes. Chapter 4.3.5 contains detailed information on this.

2.10.3 Greenhouse gas emissions caused by buildings

Buildings-related CO₂ emissions totalled 208 million tonnes in 2015, 18 % less than in 2008. Space heating was responsible for most of those emissions: 135 million tonnes of CO₂. CO₂ emissions caused by space heating experienced the greatest decrease: 23 % since 2008. The contribution by hot water (2015: 30 million tonnes CO₂) and lighting (2015: 37 million tonnes) fell by 12 % and 8 % respectively.

Air conditioning applications were responsible for 5 million tonnes of the CO₂ emissions caused by buildings in 2015. That is only 3 % of emissions related to the use of buildings. However, in contrast to the other applications, the trend is a negative one from the viewpoint of climate policy. CO₂ emissions in this area have risen 25 % since 2008.

2.11 Agriculture

2.11.1 Structure

Some 275,400 farms were managing about 16.7 million hectares of agricultural land in Germany in 2016.⁹¹ Compared with 2013, the number of farms had decreased by about 3.4 %. A more pronounced decrease (about 4.7 %) took place between 2010 and 2013.⁹² In 2016, each farm had an average of 60 hectares of land. Farms with at least 100 hectares of agricultural land cultivate about 58 % of Germany's total agricultural land.⁹³ The mean size of farms tends to decrease from east to west and from north to south. In 2016, about 60 % of the land was leased.⁹⁴ About 46 % of farms are run as a secondary occupation. This partially explains why the 1 million people who work in agriculture amount to only 0.5 million full-time equivalents.⁹⁵

In 2016, some 71 % of agricultural land was arable, 28 % was used as permanent grassland, and 1 % was used for permanent crops.⁹⁶ The main crops grown on the arable land were winter wheat (27 %), silo maize (18 %) and winter rapeseed (11 %). The amount of land used to grow energy crops (primarily silo maize, which is used as a fermentation substrate for biogas production) continues to increase,⁹⁷ although not as much as in previous years. The installed electrical capacity of biogas plants rose to over 4,000 MW in 2015.⁹⁸

There were no material changes in herd sizes. Cattle and pig stocks have remained nearly constant since 2013, and the number of sheep has increased by 3 %.⁹⁹ In contrast, the number of livestock farms is still decreasing. There were almost 14,000 fewer livestock farms (7 %) on 1 March 2016 than there were in 2013.

⁹¹ Federal Statistical Office (2017j).

⁹² Federal Statistical Office (2017j).

⁹³ Federal Statistical Office (2017k).

⁹⁴ Federal Statistical Office (2017j).

⁹⁵ Federal statistical office (2014): 2013 Survey on Agricultural Structure.

⁹⁶ Federal Statistical Office (2017j).

⁹⁷ Fachagentur Nachwachsende Rohstoffe (FNR) (2017).

⁹⁸ Fachverband Biogas (2016).

⁹⁹ Federal Statistical Office (2017j).

The share of farms using organic production methods increased from 6.3 % in 2015 to over 7 % (19,900 farms) in 2016. The share of organically farmed land in all land used for agriculture was also about 7 %.¹⁰⁰ Taking all farms (no minimum size) into account, 9.9 % of farms were using organic production methods (23,354 farms) and 7.2 % of land was farmed organically (1,251,320 hectares) in 2016.¹⁰¹

The production value of German agriculture in 2015 was around EUR 51.7 billion, almost half of which came from crop cultivation and livestock raising.¹⁰² Milk alone accounted for some 18 % of total production value. It should be noted for crop cultivation that forage crops are regarded an internal input within the sector, because they are needed for livestock raising.

2.11.2 Effects on greenhouse gas emissions

Agriculture contributed around 8 % to German greenhouse gas emissions in 2015.¹⁰³

Most agricultural greenhouse gas emissions are caused by the use of agricultural land and by digestion-related methane emissions from livestock raising. Other causes are the handling of manure, liming, and the application of urea. Emissions from land use changes caused by agriculture, such as draining peatlands or ploughing grassland, are not allocated to agriculture and instead are counted under land use, land use change and forestry (LULUCF), in accordance with climate reporting practice. About 70 % of bog lands are used for agricultural purposes. They make up only 5 % of agricultural land but emit 4 % of total German greenhouse gases. The Sixth National Communication contains a detailed discussion of measures to reduce greenhouse gas emissions from bog lands.

Ploughing up grassland, which releases large amounts of greenhouse gases, also affects greenhouse gas emissions by agriculture. The share of grasslands in total land used for agriculture in Germany declined continuously after 1993 but has stabilised at 28 % since 2011. Some 4.7 million hectares of land were used as permanent grassland in 2016.¹⁰⁴

Studies show that organic farming is generally more climate friendly than conventional agriculture, based on unit of land area. The reason for this is primarily the use of mineral fertilisers in the conventional sector, because they cause high levels of greenhouse gas emissions when they are manufactured and used. Conversely, organic farming requires more land and can cause higher greenhouse gas emissions than conventional agriculture, based on products. However, this is to a large extent dependent on how each farm is managed.

Greenhouse gas emissions by German agriculture are influenced by multiple factors, particularly regulatory background conditions and funding instruments under the Common Agricultural Policy (CAP).

The requirements of the Fertiliser Application Regulation (Düngeverordnung) should be mentioned when considering regulatory law (see Chapter 4.3.10).

The German government and the Länder, as well as the EU and the Länder, fund many different measures under the second pillar of the CAP as part of the Joint Task for the

¹⁰⁰ Federal Statistical Office (2017j).

¹⁰¹ Federal Office for Agriculture and Food (BLE) (2017).

¹⁰² Federal and Länder Statistical Offices (2017).

¹⁰³ Federal Environment Agency (2017c). The Climate Action Plan 2050 allocates both direct energy-related emissions from source category 1.A.4.c and from source category 3 to agriculture.

¹⁰⁴ Federal Statistical Office (2017j).

Improvement of Agricultural Structures and Coastal Protection (GAK), and they are having a positive influence on greenhouse gas emissions by the sector. They include advice on using fertiliser, subsidies for investments in covering liquid manure and digestion residue storage units, subsidies for certain liquid manure application methods and compensation for limitations on cultivation methods (complete or partial abandonment of fertiliser use).

When allocating emissions to the agriculture sector, the Climate Action Plan 2050 includes not only emissions from the Greenhouse Gas Inventory's agriculture source category but also agriculture's direct energy-related emissions. This deviates from the source category principle of greenhouse gas reporting. This difference in how agricultural emissions are defined explains the differences in data between the Climate Action Plan 2050 and this report.

2.12 Forests and forestry

2.12.1 Structure

Selling wood is the most important source of income for owners of forests. Germany has a total of 2 million private forest owners, who are responsible for some 48 % of forested areas. Municipal forests account for another 19 %, while state forests make up about 33 % of forested land. This range of ownership makes an important contribution to the diversity of forests, as do the different conditions in the various locations. Some 64,000 people who are employed in state, municipal and private forestry operations are responsible for annual sales of €5.8 billion.¹⁰⁵

Forestry and timber clusters contributes some EUR 178 billion in gross value added to the German economy and 1.1 million jobs. Some 76 % of value added by the German timber industry is based on softwood.¹⁰⁶ The sawmill industry produces 20 million m³ of softwood timber but only 1 million m³ of hardwood timber. Sales of softwood are closely tied to use in the construction sector. Potential applications for hardwoods have not yet been fully utilised, primarily for technical reasons.

2.12.2 Effects of forests and forestry on greenhouse gas emissions

Germany's forests sequestered 1.15 billion tonnes (or 1,148 Mt of carbon (C) (about 103 tonnes/hectare) in tree biomass in 2012, 86.4 % in above-ground biomass and 13.6 % in roots.

Germany's forests served as sinks in 2015, capturing 57.7 Mt CO₂e. Of that, 45.4 Mt CO₂ was sequestered due to the growth of plant mass, 15.6 Mt CO₂ was stored in mineral soils and 0.1 Mt CO₂ in litter. Dead wood released 2.0 million tonnes of CO₂, and organic soils released 1.2 million tonnes of CO₂. Other emissions in small amounts included 0.16 Mt CO₂e of nitrous oxide and 0.02 Mt CO₂e of methane.¹⁰⁷

Based on the 2002 federal forest inventory (BWI 2002) and the 2008 inventory study (IS08), an increase in forest carbon stocks of 0.43 t C ha⁻¹ a⁻¹ is expected for Germany as a whole. Using the data from BWI 2012, combined with the data from IS08 and BWI 2002, it was

¹⁰⁵ Ibid, data for 2014.

¹⁰⁶ Ibid.

¹⁰⁷ Due to changes in emission factors, the greenhouse gases that are included and the methods that are used, total emissions differ from earlier data.

possible to calculate a further change in forest carbon stocks for the 2008-2012 period amounting to 1,03 t C ha⁻¹ a⁻¹.

The sink performance of forests in Germany is trending downward due to a shift in the distribution of the age classes of trees and the concomitant reduction in tree growth, as well as changes in the use of wood. In addition to the sequestration of carbon in wood, the forest floor also ties up large quantities of carbon.

When accounting for forestry's contribution to climate change mitigation, it must be kept in mind that emissions that are avoided by producing materials and energy from wood that is directly related to the raw material supplied by the forestry sector are not classified under that source category. Instead, the reduced emissions are reflected in the energy industry, construction and housing, transport and industry and business sectors or source categories.

For example, it is estimated that the use of biogenic solid fuels to generate electricity and heat reduced CO₂ emissions in Germany by 31 million tonnes in 2014. The Thünen Institute also estimates that replacing energy-intensive raw materials with wood brought about similar reductions in emissions that are attributed to other sectors. However, both estimates also include biogenic solids of foreign origin. Emissions associated with supplying them may therefore be reported in the greenhouse gas inventories of other countries.

2.12.3 Structure

Selling wood is the most important source of income for owners of forests. Germany has a total of 2 million private forest owners, who are responsible for some 48 % of forested areas. Municipal forests account for another 19 %, while state forests make up about 33 % of forested land. This range of ownership makes an important contribution to the diversity of forests, as do the different conditions in the various locations. Some 64,000 people who are employed in state, municipal and private forestry operations are responsible for annual sales of €5.8 billion.¹⁰⁸

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2.12.4 Effects of climate change on forests and forestry

The extent, direction and speed of current climate change could exceed the ability of forests to adapt. Forests may suffer from heat and drought stress as summer heat and the length of dry phases increase. Extreme weather events can cause early leaf drop and slow growth. The dry, warmer regions of eastern and south-west Germany, locations with a generally poor water supply, and stands that are not adapted for other reasons are at particular risk. The risk of forest fires may also increase. The risk of losses due to pests such as bark beetles will rise at the same time as stress increases. Mass propagation of pests such as nun moths and cockchafers may occur more frequently, and pests that have previously been unimportant or disregarded may increase.

¹⁰⁸ Ibid, data for 2014.

¹⁰⁹ Ibid.

Mountain forests in the Alps could be particularly affected by climate change. Climate change could have a greater effect there than in the lowlands. The risk of natural hazards (heavy snowfall, mudslides, floods and falling rock) could increase considerably. That could further increase the importance of forests for protecting settlements and infrastructure.

However, climate change is only one of the multiple stress factors faced by forests, which include exposure to air pollution. The growing conditions for spruce, in particular, could worsen in many places if, as expected, temperatures increase, more dry phases occur, and storm events become more frequent in Central Europe. As the most common tree species, spruce is economically important and plays a primary role in forestry.

3 Information on the Greenhouse Gas Inventory

The descriptions in this chapter are based on the 2017 National Inventory Report. Germany submitted its most recent National Inventory Report (NIR 2017) in April 2017 together with the Greenhouse Gas Inventories covering the period from 1990 to 2015. It describes the methods and data sources on which the calculations of German greenhouse gas emissions are based. Please refer to NIR 2017 for further details and for information on the determination and calculation of emission inventories.¹¹⁰

Information on the direct greenhouse gases carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃) is provided below.

3.1 Presentation, determination and structure of emission data

Greenhouse gas emissions in Germany are presented for the years 1990 to 2015 in summary tables and tables showing trends for specific substances. To illustrate changes in emissions, those trends are also presented in graphic form.

Detailed information on emissions is contained in inventories published annually in the Common Reporting Format (CRF) and in the CTF tables in the Annex to the third Biennial Report. The data used in this report corresponds to the emission data submitted to the UNFCCC on 15 April 2017.¹¹¹

3.2 Accuracy of emission data

Emission inventories are fraught with uncertainty. Whereas uncertainties are determined when data is collected and therefore during the emissions reporting process, the aggregation of such uncertainties cannot take place until the inventory is generated.

In the calculation and aggregation of uncertainties, the uncertainties concerning activity rates and emission factors, which have usually been estimated by experts at the lowest level of the categories in the ZSE (Central Emission System) database used to calculate emissions, are converted into uncertainties for emissions and aggregated. Aggregation of the uncertainties according to Tier 1 as specified in the 2006 IPCC Guidelines¹¹² is done once a year at the end of the reporting cycle for the current reporting year. Uncertainty is also estimated using the IPCC Tier 2 method every three years.

Germany has reported uncertainties determined using the Tier 1 method in the current NIR 2017. This involved having the individual uncertainties estimated by the experts from the specialised units at the Federal Environment Agency (UBA) who supplied the data and by outside institutions.

The total uncertainty of the Inventory for 2015 according to Tier 1 is 4.5 % (level) or 5.1 % (trend).

¹¹⁰ Federal Environment Agency (2017c).

¹¹¹ The CRF tables of the National Greenhouse Gas Inventories are available at:

http://unfccc.int/files/national_reports/annex_i_ghg_inventories/national_inventories_submissions/application/zip/deu-2017-crf-11apr17.zip .

¹¹² Intergovernmental Panel on Climate Change (IPCC) (2006).

Total nitrous oxide emissions were a major contributor to the overall uncertainty, primarily due to nitrous oxide emissions from agricultural soils (CRF 4.D).

CO₂ emissions from the fuel combustion sector (CRF 1.A) also make a considerable contribution to the total uncertainty. Solid fuels from public electricity and heat production (CRF 1.A.1.a), transport (CRF 1.A.3), especially road transport (CRF 1.A.3.b), and combustion by commercial/institutional activities and households (CRF 1.A.4.a/b) predominate.

Other major contributors are CO₂ sinks and sources from the LULUCF sector and methane emissions from solid waste disposal (CRF 6.A) and livestock raising (enteric fermentation, CRF 4.A).

3.3 Greenhouse gas emissions 1990–2015

In the context of the first commitment period of the Kyoto Protocol from 2008 to 2012, the European Community (which had 15 Member States at that time) pledged to reduce its greenhouse gas emissions by 8 % from the base year (1990 or 1995). That commitment was divided among the Member States as part of burden sharing and was fulfilled. With its commitment to reduce emissions by 21 % from the base year, Germany made a considerable contribution to fulfilment of the EU commitment. This target was exceeded by 2012, with a reduction of 23.6 %.¹¹³

The main reasons for these trends are as follows:

- Change from the use of solid fuels to lower-emission liquid and gaseous fuels since 1990;
- Increased use of renewable energy sources and the associated substitution for fossil fuels;
- More efficient plants and facilities;
- Changes in livestock raising conditions and reduction in livestock populations;
- Compliance with statutory provisions on waste management.

In the context of the second commitment period of the Kyoto Protocol that began in 2013, the European Union and Iceland committed to reducing the release of greenhouse gas emissions by 20 % by 2020.

Over and above this, at the national level Germany set itself the goal of reducing its greenhouse gas emissions by at least 40 % by 2020 compared with 1990.

By 2015, emissions of greenhouse gases overall were 27.9 % below 1990 levels.¹¹⁴ A closer look at the individual components reaffirms this trend in its varying degrees for the different gases. Changes in emissions since 1990 of the principal greenhouse gases in terms of quantity amounted to minus 24.7 % for carbon dioxide (CO₂), minus 53.4 % for methane (CH₄) and minus 39.3 % for nitrous oxide (N₂O). By contrast, the trend for F-gases, which account for about 1.6 % of greenhouse gas emissions, is not quite so uniform. As a result of the introduction of new technologies and the use of these substances as substitutes, emissions of SF₆ fell by 19.6 % and of PFCs by 91.7 % compared with 1990,

¹¹³ UNFCCC (2016).

¹¹⁴ The above figures do not take account of emissions from the land use, land use change and forestry (LULUCF) category.

whereas emissions of HFCs rose by 92.8 %. Emissions of NF_3 , a greenhouse gas which is included in the report for the first time, have risen very markedly since 1990 – by 71.4 % – but their contribution to overall emissions, at approximately 0.001 %, is extremely small.

Changes in greenhouse gas emissions in Germany since 1990 are shown in Table 6 for the individual greenhouse gases and as total CO₂ equivalents in graphic form.

Emission trends (kt CO ₂ equivalents)	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Net CO ₂ emissions/sinks (including LULUCF)	1,019,229	903,409	859,653	852,192	814,391	795,156	800,967	819,417	778,240	775,753
CO ₂ emissions (excluding LULUCF)	1,052,247	938,150	899,286	865,866	832,437	812,577	817,145	835,459	794,829	792,054
CH ₄ including LULUCF	121,169	105,831	88,608	69,344	59,127	58,002	58,645	58,037	56,874	56,483
CH ₄ excluding LULUCF	120,293	104,960	87,736	68,478	58,260	57,136	57,778	57,171	56,009	55,616
N ₂ O including LULUCF	65,819	61,783	43,890	44,204	37,602	39,016	38,190	38,766	39,437	39,933
N ₂ O excluding LULUCF	64,989	60,968	43,088	43,455	36,794	38,195	37,354	37,925	38,590	39,078
HFCs	5,891	8,217	7,806	9,940	10,753	10,953	11,140	11,096	11,183	11,356
PFCs	3,060	2,087	959	839	346	279	243	257	235	254
SF ₆	4,428	6,467	4,072	3,320	3,100	3,163	3,155	3,261	3,396	3,562
NF ₃	7	5	9	34	61	61	35	16	20	12
Total emissions/sinks including LULUCF	1,219,604	1,087,801	1,004,997	979,873	925,382	906,630	912,374	930,851	889,385	887,352
Total emissions excluding LULUCF	1,250,915	1,120,856	1,042,958	991,933	941,750	922,363	926,850	945,186	904,262	901,932
Emission trends	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Changes compared with 1990					(%)					
Net CO ₂ emissions/sinks		-11.4	-15.7	-16.4	-20.1	-22.0	-21.4	-19.6	-23.6	-23.9
CO ₂ emissions (excluding		-10.8	-14.5	-17.7	-20.9	-22.8	-22.3	-20.6	-24.5	-24.7

LULUCF)										
CH ₄ (including LULUCF)		-12.7	-26.9	-42.8	-51.2	-52.1	-51.6	-52.1	-53.1	-53.4
N ₂ O (including LULUCF)		-6.1	-33.3	-32.8	-42.9	-40.7	-42.0	-41.1	-40.1	-39.3
HFCs		+39.5	+32.5	+68.7	+82.5	+85.9	+89.1	+88.4	+89.8	+92.8
PFCs		-31.8	-68.7	-72.6	-88.7	-90.9	-92.1	-91.6	-92.3	-91.7
SF ₆		+46.0	-8.0	-25.0	-30.0	-28.6	-28.7	-26.4	-23.3	-19.6
NF ₃		-28.6	+28.6	+385.7	+771.4	+771.4	+400.0	+128.6	+185.7	+71.4
Total emissions/sinks including LULUCF		-10.8	-17.6	-19.7	-24.1	-25.7	-25.2	-23.7	-27.1	-27.2
Total emissions excluding LULUCF		-10.4	-16.6	-20.7	-24.7	-26.3	-25.9	-24.4	-27.7	-27.9

Emission trends	1990	1995	2000	2005	2010	2011	2012	2013	2014	2015
Changes from previous year	(%)									
Net CO ₂ emissions/sinks		-0.2	+0.2	-2.6	+5.9	-2.4	+0.7	+2.3	-5.0	-0.3
CO ₂ emissions (excluding LULUCF)		-0.1	+0.4	-2.3	+5.6	-2.4	+0.6	+2.2	-4.9	-0.3
CH ₄ (including LULUCF)		-2.2	-4.7	-4.5	-1.4	-1.9	+1.1	-1.0	-2.0	-0.7
N ₂ O (including LULUCF)		-0.9	+0.1	-4.4	-17.5	+3.8	-2.1	+1.5	+1.7	+1.3
HFCs		+2.6	-11.6	+3.4	-3.7	+1.9	+1.7	-0.4	+0.8	+1.5
PFCs		+8.7	-35.5	-14.3	-15.1	-19.4	-13.0	+6.1	-8.8	+8.1
SF ₆		+3.5	-5.1	+2.4	+6.0	+2.0	-0.3	+3.4	+4.1	+4.9
NF ₃		-23.1	+33.4	+51.2	+111.2	-0.4	-42.5	-54.5	+26.5	-41.4
Total emissions/sinks including LULUCF		-0.4	-0.4	-2.8	+4.1	-2.0	+0.6	+2.0	-4.5	-0.2

Total emissions excluding LULUCF	-0.3	-0.2	-2.5	+3.8	-2.1	+0.5	+2.0	-4.3	-0.3
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Table 7: Emission trends in Germany since 1990, by greenhouse gas¹¹⁵

¹¹⁵ Federal Environment Agency (2017c).

In 2015, release of carbon dioxide was once again the main contributor to greenhouse gas emissions, accounting for 87.8 %. Most of them came from stationary and mobile combustion of fossil fuels. The relative share of CO₂ emissions in total greenhouse gas emissions has risen by about 3.5 percentage points since the base year, due to the disproportionate reduction in emissions of other greenhouse gases. Methane (CH₄) emissions, most of which are caused by livestock raising, fuel distribution and landfills, accounted for a 6.2 % share. Most emissions of nitrous oxide (N₂O) came from agriculture, industrial processes and the combustion of fossil fuels, contributing 4.3 % to greenhouse gas emissions. Fluorinated gases (known as F-gases) contributed about 1.7 % to total emissions; NF₃, a greenhouse gas which has only recently been included in the reporting, contributed a negligible share of 0.001 %.

The distribution of greenhouse gas emissions in Germany is typical of a highly developed, industrialised country.

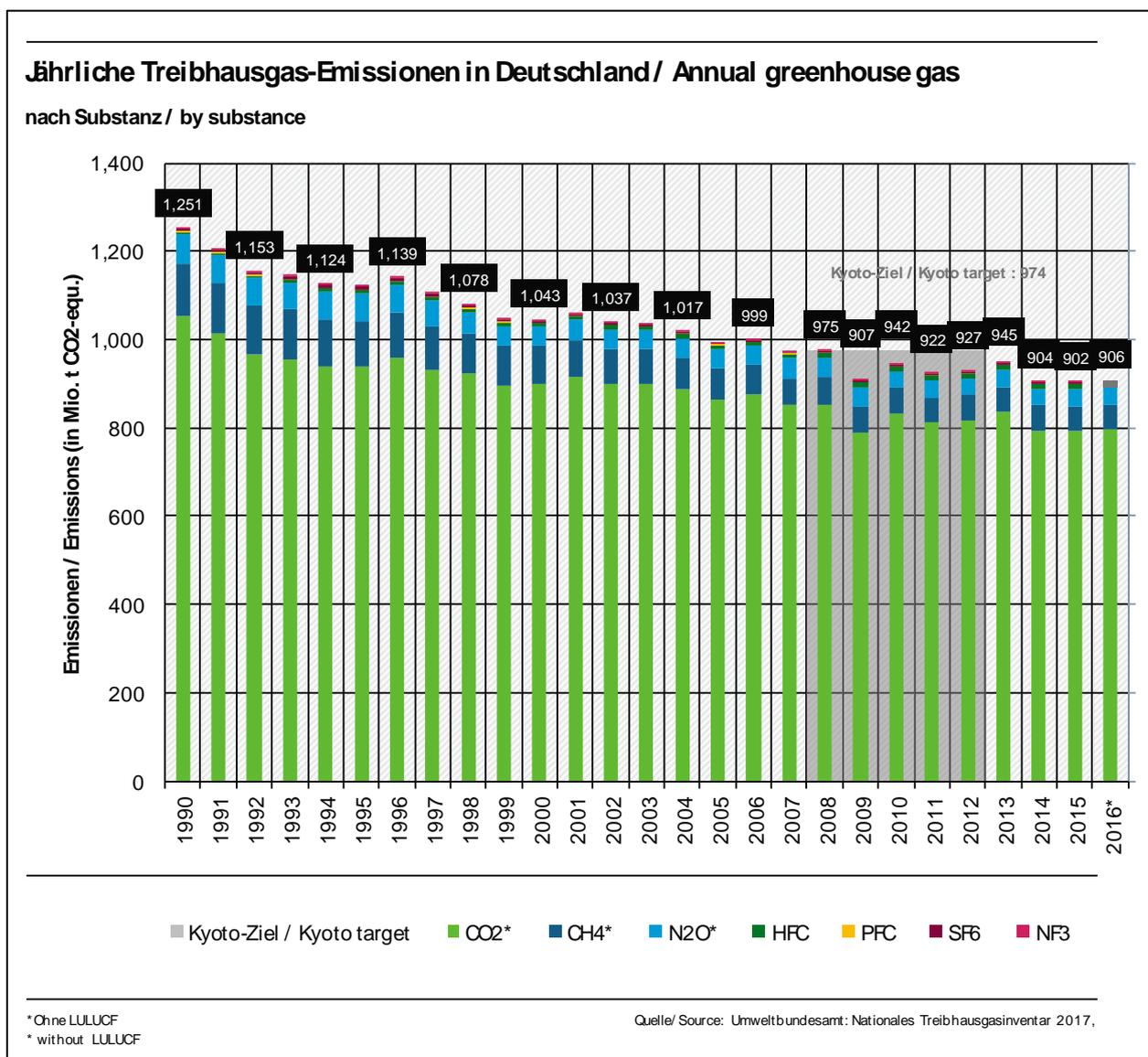


Figure 20: Trends in greenhouse gases in Germany since 1990, by individual gas¹¹⁶

¹¹⁶ Federal Environment Agency (2017c).

The trends for these developments, based on 1990, are summarised in Figure 21. Major reductions in the direct greenhouse gases that are present in the largest quantities were achieved during the period under consideration.

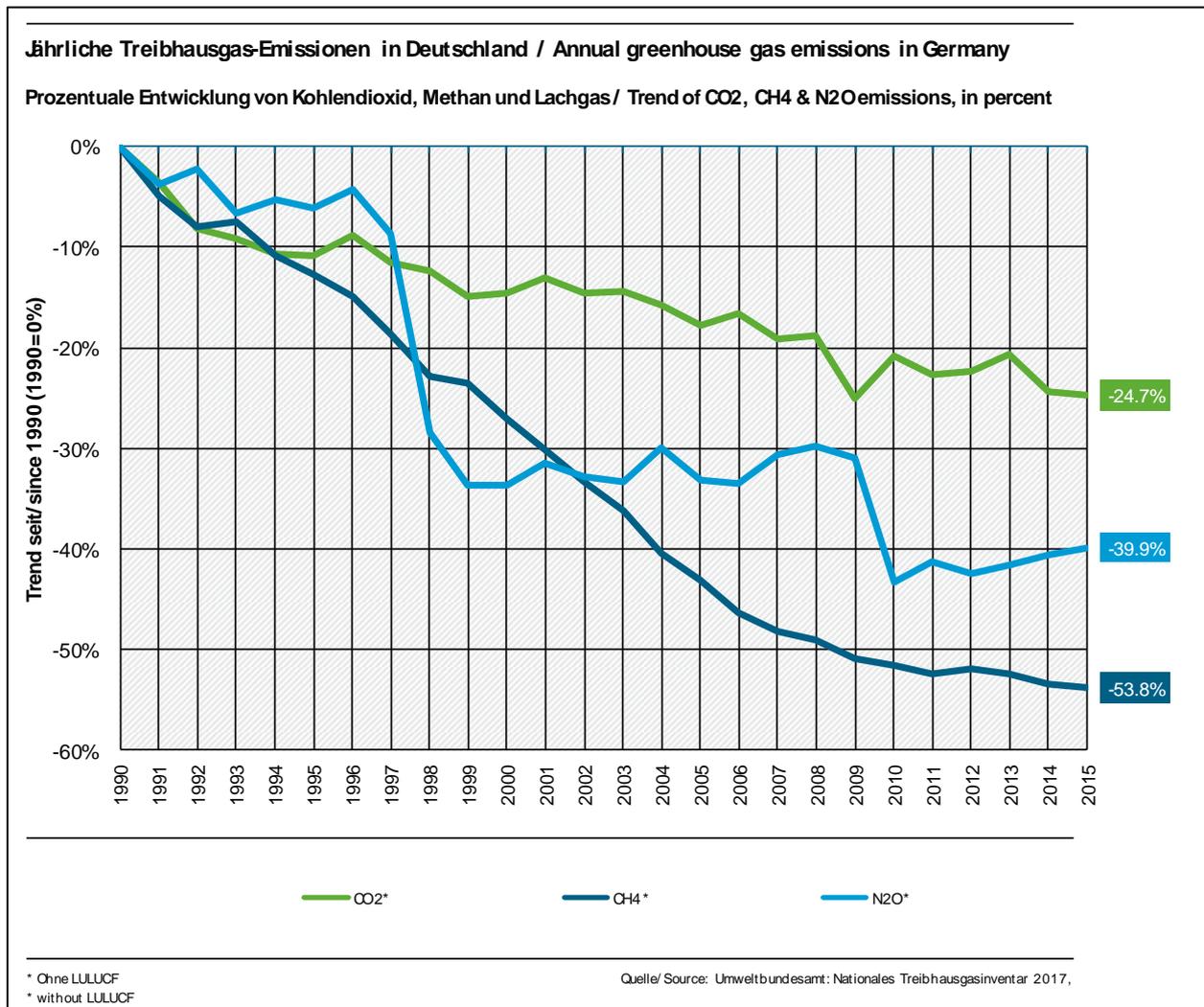


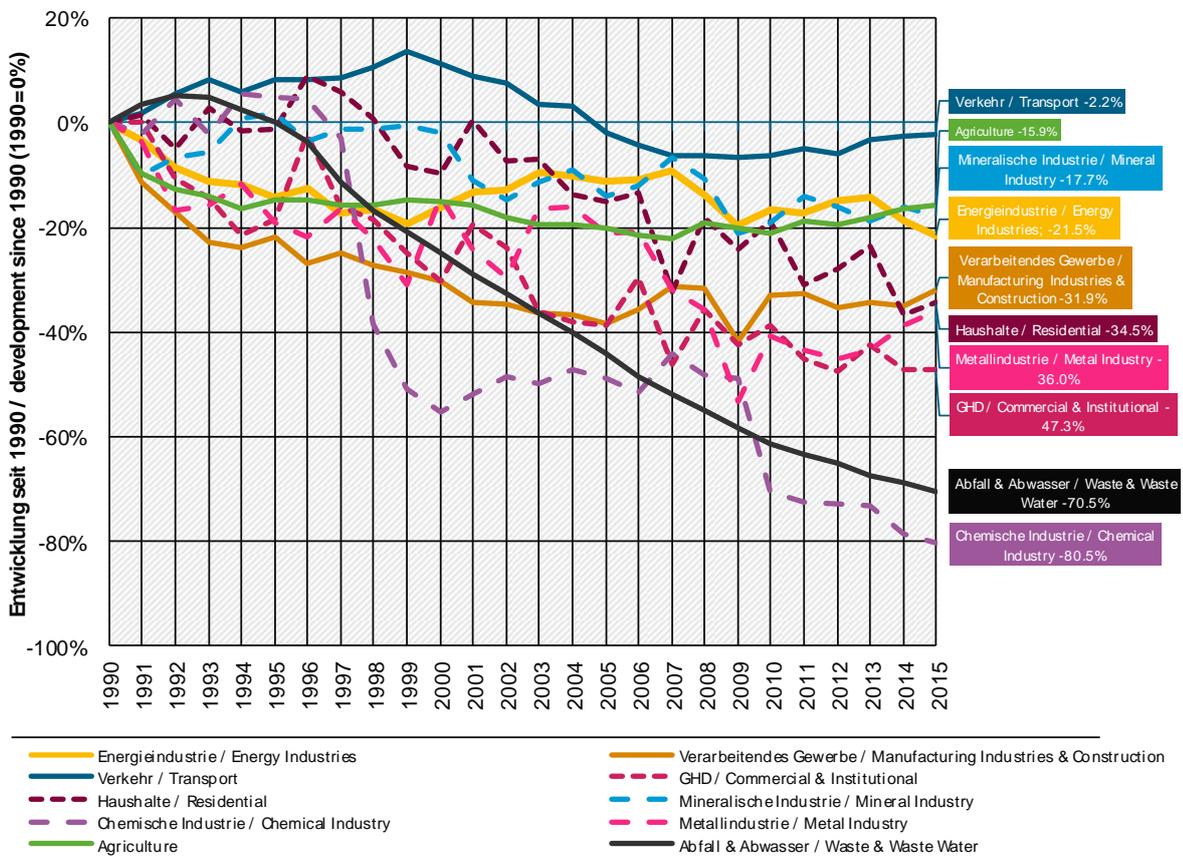
Figure 21: Relative development of greenhouse gas emissions since 1990¹¹⁷

Figure 22 shows the relative development of emissions by category since 1990. The trend for each of these greenhouse gases is largely dominated by specific developments in one category. For example, the reduction in CO₂ emissions is closely linked to trends in the energy sector.

¹¹⁷ Federal Environment Agency (2017c).

Jährliche Treibhausgas-Emissionen in Deutschland / Annual greenhouse gas

Prozentuale Entwicklung der relevanten Kategorien seit 1990 / Trend of the relevant categories since 1990, in percent



Quelle/ Source: Umweltbundesamt: Nationales Treibhausgasinventar 2017.

Figure 22: Trends in greenhouse gas emissions since 1990 by category¹¹⁸

¹¹⁸ Federal Environment Agency (2017c).

3.3.1 Carbon dioxide (CO₂)

The reduction in CO₂ emissions is closely linked to trends in the energy sector. The sharp reduction in emissions in this area seen in the early 1990s was primarily the result of restructuring in the "new" German Länder (of former East Germany). The changes in the fuel mix have continued, to a somewhat lesser degree, up to the current report year.

Use of gases, primarily natural gas, as substitutes for solid and liquid fuels is also reflected in emissions trends for stationary combustion systems. While CO₂ emissions from liquid fuels decreased by about 23 % with respect to their levels in 1990, and emissions from solid fuels by as much as about 40 %, emissions from gaseous fuels increased by roughly 25 %.

When these emissions trends are viewed at the level of individual categories, a highly consistent picture emerges. In comparison to 1990 levels, CO₂ emissions in all sub-categories of energy-related emissions decreased by a total of nearly 244 million tonnes.

Trends in the transport sector, which is dominated by road transport, are somewhat different: CO₂ emissions increased significantly between 1991 and 2000, before declining in the period up to 2009. The decline in emissions from road transport is partly due to improvements in efficiency, the use of diesel fuel as a substitute for petrol and the blending of biodiesel. As a result of rising traffic volumes and a decrease in the use of biofuels, a steady rise in CO₂ emissions was observed from 2012 again. At around 159 million tonnes, CO₂ emissions from the transport sector were reduced only slightly compared with their starting level in 1990 (roughly 162 million tonnes).

3.3.2 Nitrous oxide (N₂O)

Since 1990, N₂O emissions have decreased by about 40 %. The main emissions sources are the use of nitrogen-containing fertilisers in agriculture, the use of fossil fuels and livestock raising. Smaller amounts of emissions are caused by wastewater treatment, the chemical industry and the use of N₂O in products (for example as an anaesthetic). Industry has had the greatest influence on emissions reductions, especially in the area of adipic acid production as a consequence of abatement systems being fitted in 1997 and 2009. As a result of technological reduction measures, emissions from the chemical industry have been reduced by about 96 % with respect to 1990. Since 1999, emissions trends have been strongly influenced by economic trends in the chemical industry.

3.3.3 Methane (CH₄)

Methane emissions are caused mainly by livestock husbandry, landfilling waste and the distribution of liquid and gaseous fuels. Energy-related and process-related emissions and emissions from wastewater treatment play an almost negligible role. Methane emissions have been reduced by over 53 % since 1990. The key driver of this trend has been the decline in the amount of biodegradable organic waste sent to landfill. A second important factor is that energy recovery from coal mine gas has increased, while overall production of such gas has decreased (due to the closure of coal mines). Emissions in this area have decreased by nearly 76 % since 1990. Yet another reason for the emissions reductions is that livestock populations in the former East Germany have been reduced, with reductions occurring especially in the first half of the 1990s. Repairs and modernisations of outdated gas distribution networks in that part of Germany, along with improvements in fuel distribution, have brought about further reductions in total emissions.

3.3.4 F-gases

HFC emissions increased primarily as a result of intensified use of HFCs as refrigerants in refrigeration systems and of increasing disposal of those systems. This more than offset emissions reductions resulting from their reduced use in PUR installation foams. The emissions reductions for PFCs were achieved primarily through efforts of primary aluminium producers and semiconductor manufacturers. The SF₆ emissions reduction up to 2003 is due primarily to use of the gas in automobile tyres being phased out since the mid-1990s. In this area, efforts to increase environmental awareness have been successful, resulting in emissions reductions of over 100 tonnes and greenhouse gas reductions of 2.5 million tonnes of CO₂ equivalents. Similar success has been achieved with soundproof windows, for which production use of SF₆ has been reduced to nearly zero. The majority of current and future emissions of this substance will result from open disposal of old windows. Emissions from electricity transmission facilities have also decreased considerably. Important new emissions sources include welding, production of solar cells and production of glass fibre optics.

In Germany, NF₃ is used only in the production of semiconductors and photovoltaic systems. NF₃ emissions accounted for 0.0013 % of total greenhouse gas emissions in 2015. In light of their lack of relevance to overall greenhouse gas emissions, no separate trend analysis is provided here.

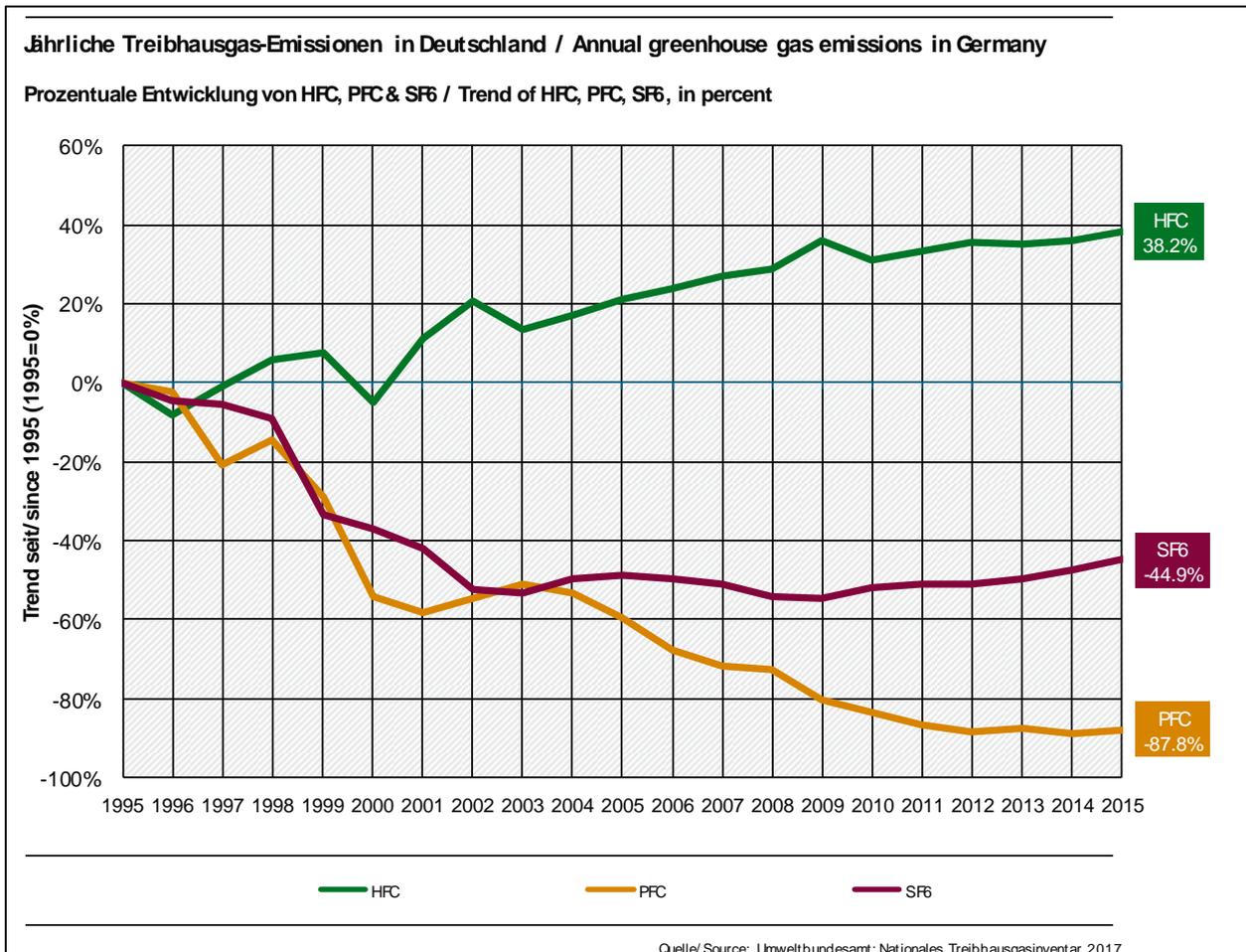


Figure 23: Relative development of F-gas emissions since 1995¹¹⁹

3.4 National System of Emissions Inventories

The National System for Germany fulfils the requirements of the UNFCCC Guidelines for National Systems, which are binding under the Kyoto Protocol, and the EU regulation on a mechanism for monitoring and reporting greenhouse gas emissions. Since the 2015 Inventory Report, the requirement to report on the national institutional provisions has also been included in the Framework Convention on Climate Change.

The National System serves to ensure that preparation of the inventories conforms to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through use of the methodological regulations from the revised IPCC Guidelines for National Greenhouse Gas Inventories of 2006.

Germany set up its National System by 2011.

¹¹⁹ Federal Environment Agency (2017c).

Single National Entity at the Federal Environment Agency

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The National System was essentially institutionalised on three levels in Germany: the ministerial level of the federal government, the level of the Federal Environment Agency and the level outside of the federal administration.

At ministerial level, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) is the lead agency. The participating ministries are the Federal Ministry of Food and Agriculture (BMEL), Federal Ministry of Finance (BMF), Federal Ministry of the Interior (BMI), Federal Ministry of Transport and Digital Infrastructure (BMVI), Federal Ministry of Defence (BMVg) and Federal Ministry for Economic Affairs and Energy (BMWi). The participating ministries coordinate their work through a coordinating committee.

The Federal Environment Agency is the Single National Entity for Germany. The tasks incumbent on the Single National Entity include planning, generating and archiving the inventories, and quality control and quality assurance. The Single National Entity is the central contact point and coordinates and provides information to everyone involved in the National System. Many institutions and non-governmental organisations outside of the federal administration are integrated into the National System.

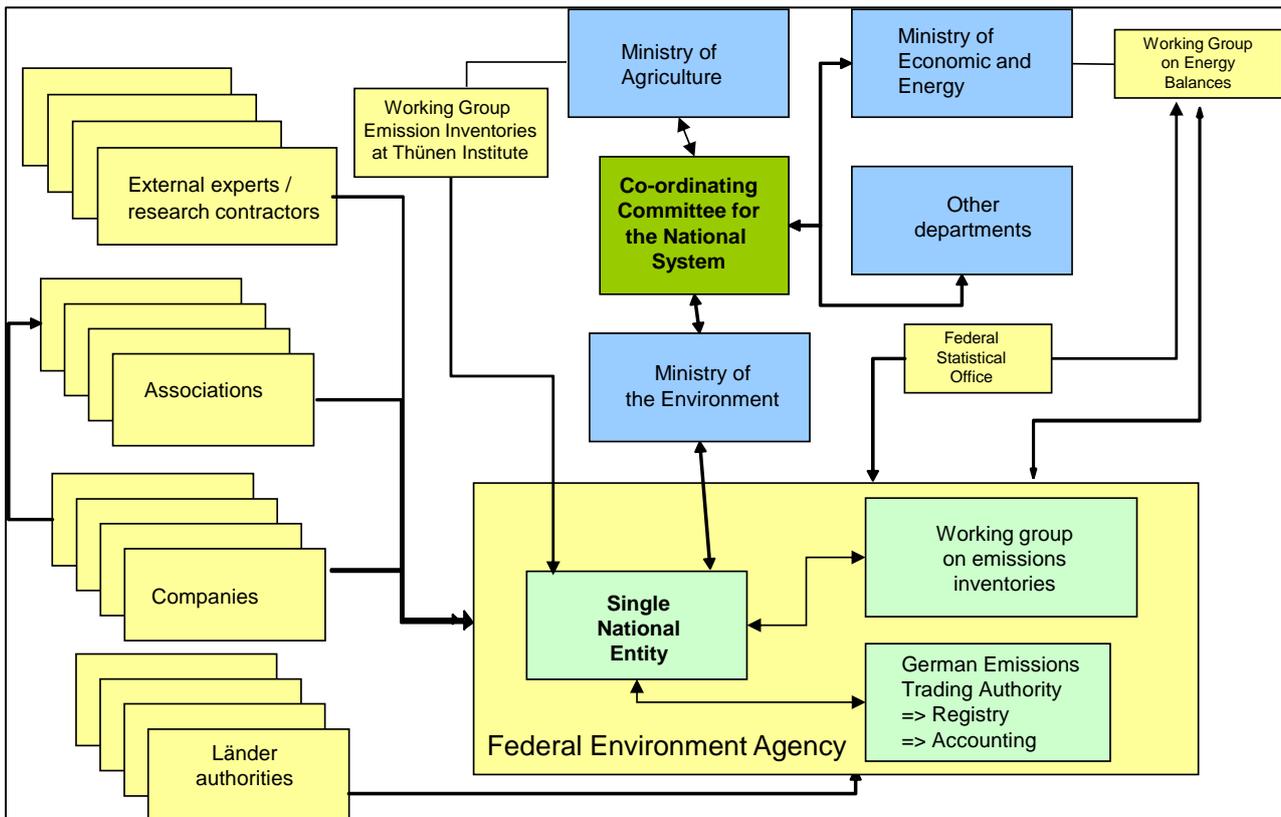


Figure 24: Structure of the National System of Emissions (NaSE)¹²⁰

¹²⁰ Federal Environment Agency (2017c).

3.5 Description of the National Registry

Directive 2009/29/EC, adopted in 2009, provides for the centralisation of the EU ETS operations into a single European Union registry operated by the European Commission as well as for the inclusion of the aviation sector. At the same time, and with a view to increasing efficiency in the operation of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol (25) plus Iceland, Liechtenstein and Norway decided to operate their registries in a consolidated manner in accordance with all relevant decisions applicable to the establishment of Party registries.

With a view to complying with the requirements of Commission Regulation 389/2013, the EU registry has undergone a major redevelopment, which was described in detail in the Sixth National Communication. The consolidated platform which implements the national registries in a consolidated manner (including the EU registry) is called the Consolidated System of EU Registries (CSEUR) and was developed together with the new EU registry.

Following the successful implementation of the CSEUR platform, the 28 national registries concerned were re-certified in June 2012 and switched over to their new national registries on 20 June 2012. During the go-live process, all relevant transaction and balance data were migrated to the CSEUR platform and the individual connections to and from the ITL were re-established for each Party.

4 Policies and measures

Tackling climate change has been a prominent part of German policymaking for more than two decades. This is based on a comprehensive strategy that the German government has constantly developed. The mainstays are the Climate Action Plan 2050, the Climate Action Programme 2020 and Germany's energy transition, which are described below in greater detail.

In preparation for the 2017 German Projections Report, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) commissioned a research consortium to develop scenarios to predict how greenhouse gas emissions in Germany might develop from 2005 to 2035. The with-measures scenario (WMS), which includes the new climate and energy-policy measures introduced or substantially changed in various sectors before July 2016, forms the basis for the description and evaluation of the measures and instruments in this chapter. Institutional measures and climate change mitigation activities by the Länder and local authorities were not modelled or considered in the 2017 Projections Report. The German government does not fully endorse the scenarios of the 2017 Projections Report for the period 2005 to 2035, but it will ensure that the research findings are taken into account in its future deliberations.¹²¹

4.1 Climate policy processes

Three key mainstays of German climate policy are described below: Germany's long-term climate action strategy, the Climate Action Plan 2050; the Climate Action Programme 2020, geared to the targets for 2020; and Germany's energy transition.

4.1.1 Climate Action Plan 2050

4.1.1.1 Targets and content

In November 2016, the German government adopted the country's long-term climate action strategy – the Climate Action Plan 2050 – as required under the Paris Agreement. It was one of the first countries to do so. The government established the goal of being largely greenhouse neutral by mid-century as its guiding principle. In addition, the Climate Action Plan spelled out the government's 2030 climate target of at least minus 55 % for the individual sectors, described development pathways in those sectors, agreed initial implementation measures and set up a process for monitoring and refining the policies and measures. The Climate Action Plan is constructed as an ongoing “learning system” that is able to respond to developments without being tied to specific technologies. This strategy is the means by which Germany will play its part in achieving the Paris Agreement's global aim to limit global warming to well below 2 degrees Celsius and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius.

The Climate Action Plan builds on the long-term climate targets previously adopted in 2010 (see Sixth National Communication, Chapter 3.1) and makes them more specific in light of the Paris Agreement.

¹²¹ 2017 Projections Report, supplied by: Öko-Institut; German version available at http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/; English version will be available in due course at <http://acm.eionet.europa.eu/>

The German government's Climate Action Plan 2050 provides guidance on achievement of the targets for a range of sectors: energy, buildings, transport, industry and business, agriculture, and land use and forestry. The Climate Action Plan 2050 outlines a transformation pathway. Businesses, trade unions, associations and civil society were all closely involved in drafting the plan through a dialogue process.

The Climate Action Plan 2050 describes a modernisation strategy for the necessary transformation to a low-carbon economy on three levels:

1. It contains specific guiding principles for the individual areas of action for 2050, creates space for innovation and strives to maximise environmental protection, social equity and economic performance.
2. It outlines robust transformation pathways for all areas of action, examines critical path dependencies and describes interdependencies.
3. It underpins goals, in particular the interim GHG target for 2030 of achieving at least a 55 % reduction with emissions targets for all sectors, with specific milestones and strategic measures, and includes impact and cost analyses.

When deciding how to transition to a greenhouse gas-neutral economy and society, the management rules, targets and other requirements of the government's sustainability strategy must be taken into account. Climate action that is successful over the long term must go hand in hand with sustainable use and conservation of resources and must not threaten the preservation of biodiversity. With a view to meeting the 17 Sustainable Development Goals (SDGs) of the United Nations, the focus should be on reducing greenhouse gases by increasing energy efficiency. Social and economic requirements must be considered when structuring the transformation.

4.1.1.2 Monitoring and updating

The German government prepares climate action reports every year so that it can regularly examine implementation and the fulfilment of goals, and it will continue to do this after 2020 so that any necessary adjustments can be made. The climate action reports follow the existing format to show progress in implementing measures under the current programmes of measures, current trends for emissions in the various areas of action and an estimate of the reductions expected from upcoming steps.

The government's Climate Action Plan is reviewed and updated in accordance with the five-year reviewing cycle of Nationally Determined Contributions (NDCs) under the Paris Agreement. The first update will take place when the Parties to the Paris Agreement have to submit new NDCs or update or re-communicate existing NDCs, namely by late 2019 or early 2020.

The intermediate targets and milestones, the relevant transformation pathways and the associated measures will be continuously reviewed to ensure that they are consistent with achieving the targets that have been set and if necessary will be adapted. This will enable allowance to be made for technical developments and societal, political and economic trends and changes, as well as the latest scientific findings.

In 2018 the Climate Action Plan 2050 will be underpinned with a programme of measures having quantifiable effects on reductions, which is intended to ensure that the 2030 reduction target is achieved. The environmental, social and economic impacts of each programme of measures will be assessed. The programme of measures underpins each upcoming reduction step and milestone with specific actions, where possible quantified in

terms of their impact on emissions reduction. The programme of measures will be developed in consultation with the Bundestag (lower house of parliament) and with the involvement of social stakeholders, partly through the Climate Action Alliance (see below). The sectoral targets will undergo an impact assessment, the findings of which will be discussed with all social partners and will enable the sectoral targets to be modified in 2018.

Reviewing and updating the Climate Action Plan and developing and revising programmes of measures requires scientific analyses of scenarios and of the effectiveness, costs, results and ancillary effects, as well as the economic and social opportunities and risks. A scientific platform set up by the federal government, comprising selected institutions performing research in the natural and social sciences, will perform that task.

The Climate Action Plan itself will be reviewed and updated as part of a public dialogue process with broad participation by the Länder, local authorities, the private sector, civil society and the public, known as the Climate Action Alliance. The participatory processes associated with the Climate Action Plan 2050 are regularly evaluated and refined.

The German government will continue to develop a culture of participation, thereby initiating and strengthening learning and innovation processes. It is guided in particular by certain UN Sustainable Development Goals: achieving gender equality (SDG 5), reducing inequality (SDG 10), and effective and inclusive public institutions (governance; SDG 16).

4.1.2 Climate Action Programme 2020

The German government adopted the Climate Action Programme 2020 in December 2014.¹²² It did so in response to the 2013 Projections Report, which stated that the national emission reduction target of minus 40 % by 2020 would probably not be achieved with the measures that had been put in place at that time.

The report made it clear that the measures adopted and implemented by October 2012 would make it possible to achieve a reduction in greenhouse gas emissions of about 33 to 34 % by 2020, with an uncertainty of +/- 1 %. This created a corridor for the mitigation gap of between 5 and 8 percentage points. In order to reach the 40 % target, therefore, additional efforts needed to be made. The German government set these in motion with its Climate Action Programme.

4.1.2.1 Content

The Action Programme set out climate change mitigation measures in the following areas:

- Emissions trading and European and international climate policy;
- Climate change mitigation in electricity generation, including continued development of the conventional power station fleet and the expansion of renewable energy;
- National Action Plan on Energy Efficiency (NAPE), with the focus on energy efficiency in buildings, energy saving as a business opportunity and way of generating returns, and individual responsibility for energy efficiency;
- Climate-friendly building and housing strategy;
- Climate change mitigation in the transport sector;

¹²² Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014b).

- Reducing non-energy-related emissions in the industry, waste management and agriculture sectors.
- The government's role in demonstrating best practice;
- Research and development;
- Advice, public education and independent initiatives.

4.1.2.2 Process of drafting the Action Programme

Technical and economic potential was identified in all sectors during the preparatory work for the Climate Action Programme. According to various studies, potential for additional reductions was mainly to be found in the energy sector, industry, households (residential buildings) and transport. The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety also held two dialogue forums to get Länder, local authority associations and social stakeholders involved early on in the discussion on suggestions for measures in all sectors. The purpose of the first dialogue forums in June 2014 was to inform people about the planned Action Programme. The stakeholders were also asked to submit proposals for measures.

The purpose of the second dialogue forums in September 2014 was to provide the Länder, local authority associations and social stakeholders with information on how work within the federal government was progressing.

4.1.2.3 Monitoring

The German government is monitoring implementation of the Climate Action Programme in an ongoing process up to 2020. To that end, BMUB produces an annual climate action report. The climate action report contains information on the latest emissions trends in the various areas for action, implementation progress and a forecast of the reduction effects that can be expected by 2020. The 2016 climate action report,¹²³ the most recent to appear, states that almost 70 % of the around 100 measures adopted in the Action Programme have already been fully implemented, and implementation of the other measures has begun.

Furthermore, the government has also set up a Climate Action Alliance, comprising representatives from all groups of society with BMUB as lead agency. The Action Alliance supports implementation of the adopted measures and has the task of identifying further options for action. It will also be involved in drafting the first programme of measures of the Climate Action Plan 2050 (see above).

4.1.3 The German government's Energy Concept

The targets, participation formats and monitoring processes for the energy transition, described in detail in the Sixth National Communication, remain unchanged. The activities relating to the energy transition and the Climate Action Plan 2050 described above are coordinated with each other through close cooperation between the lead ministries.

The purpose of the monitoring process for the energy transition and the "Energy of the future" energy concept behind it is to be able to review and, if necessary, make adjustments to the implementation of measures including achievement of the goal of a reliable,

¹²³ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2016a).

affordable and environmentally sound energy supply. The government publishes the results of the monitoring annually. The Fifth Monitoring Report was presented in December 2016.

In addition to the regular monitoring, every three years a Progress Report provides a more comprehensive view of the energy transition, enables analyses to be conducted in greater depth over a longer period and also looks to the future. The reports are submitted to the Bundestag (lower house of parliament) and Bundesrat (upper house). The government published the Initial Progress Report in December 2014. The Second Progress Report is being drafted in the course of 2017.

A commission of independent energy experts supports the monitoring process. The expert commission gives a scientific opinion of the government's monitoring and progress reports. The monitoring process helps to increase the transparency of the energy transition and thus raise the level of acceptance.

4.2 Institutional measures and instruments for implementing the obligations under the Kyoto Protocol

4.2.1 Interministerial Working Group on CO₂ Reduction

The German government set up the Interministerial Working Group on CO₂ Reduction as far back as 1990, with the Environment Ministry as the lead agency. This working group drafted guidelines for climate action, identified areas where action was needed and proposed measures to reduce greenhouse gas emissions in Germany. The Interministerial Working Group on CO₂ Reduction submitted reports to the federal cabinet outlining a national climate action strategy in November 1990, December 1991, September 1994, November 1997, October 2000 and July 2005. The working group may continue to be used for implementation of the Climate Action Plan 2050.

4.2.2 Working Group on Emissions Trading as a Means to Combat the Impacts of Greenhouse Gases

In October 2000 the German government set up the Working Group on Emissions Trading as a Means to Combat the Impacts of Greenhouse Gases (AGE) in conjunction with the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. The federal cabinet welcomed the working group's consultations and extended its remit in the 2005 Climate Action Programme. The working group is tasked with reviewing issues arising in connection with the use of emissions trading as part of a package of climate change mitigation measures and making recommendations on the specifics of this instrument. Discussions at international, EU and national level provide the background to the working group's consultations.

4.2.3 National Emissions Reporting System

Article 5 of the Kyoto Protocol requires each Party listed in Annex B to establish a national system for emissions reporting. This requirement was implemented in Germany by a coordinating committee of all ministries involved in reporting. BMUB is the lead agency, and the Single National Entity at the Federal Environment Agency is responsible for execution.

4.2.4 German Emissions Trading Authority

The German Emissions Trading Authority at the Federal Environment Agency is the national authority responsible for implementation of market-based climate change mitigation instruments in the area of emissions trading, as well as project-based mechanisms under the Kyoto Protocol. Its duties are defined in more detail in the EU Emissions Trading Directive, the Greenhouse Gas Emissions Trading Act (Treibhausgas-Emissionshandelsgesetz – TEHG), the Allocation Regulation (Zuteilungsverordnung – ZuV 2020) and the Project Mechanisms Act (Projektmechanismengesetz – ProMechG).

The German Emissions Trading Authority actively supports plant operators, aircraft operators and specialised agencies in the proper implementation of requirements related to emissions trading and carries out corresponding checks to this end. The Authority is also the contact point for the Federal Environment Ministry, the Länder and the responsible pollution control agencies in the Länder.

4.2.5 Joint Implementation Coordination Office (JIKO)

The Joint Implementation Coordination Office, operating under the auspices of BMUB, was created in 1995 to promote, approve and monitor the joint implementation (JI) and clean development mechanism (CDM) projects specified in Articles 6 and 12 of the Kyoto Protocol. JIKO's overarching objective will continue during the second commitment period of the Kyoto Protocol, with the addition of new tasks related to the carbon market. In addition to the tasks outlined in the Sixth National Communication, JIKO also supports the development of new market mechanisms (NMMs) in line with the provisions of the 2015 Paris Agreement with a view to keeping up with perspectives for long-term international cooperation in the carbon market.

4.2.6 National Focal Point for Education on Climate Protection

As part of implementation of the UN Framework Convention on Climate Change's provisions on education, training and public awareness, BMUB set up a National Focal Point for Education on Climate Protection at the Ministry. Its purpose is to make the diverse educational activities in the area of climate change more visible as an essential element of sustainable development. The Focal Point is used as a platform for public and private players in the educational sector. Its remit includes ensuring that the many different governmental and non-governmental players in the educational field and their diverse educational activities are networked more closely within Germany's federal system.

4.2.7 Competence Centre on Climate Impacts and Adaptation

BMUB created a Competence Centre on Climate Impacts and Adaptation (KomPass) at the Federal Environment Agency to provide scientific support for the development of a national strategy for adapting to climate changes. KomPass is tasked with promoting adaptation to climate change in Germany and Europe. One of its main tasks is to refine the German Strategy for Adaptation to Climate Change (DAS) and promote its implementation.

4.3 Federal level

The sector-based measures and instruments that were considered in the 2017 Projections Report are discussed in greater detail below.

In preparation for the 2017 German Projections Report, the Federal Ministry of the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) commissioned a research consortium to develop scenarios to predict how greenhouse gas emissions in Germany might develop from 2005 to 2035. Firstly, it created a “with-measures” scenario (WMS), which includes new climate and energy policy measures in various sectors introduced by 31 July 2016 and existing measures that have been substantially changed by the same date. Secondly, it modelled a “with-additional-measures” scenario (WAMS which includes primarily the policy measures that are set out in the interministerial Climate Action Programme 2020¹²⁴ and the National Action Plan on Energy Efficiency (BMW_i 2014) but have not yet been implemented.

The scenario calculation involved a detailed analysis of the climate and energy policy measures put in place by the deadline in order to establish their effects on trends in greenhouse gas emissions in Germany. This included taking into account emissions of the greenhouse gases covered by the Kyoto Protocol – carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃) – for the source categories energy, industrial processes, product use, agriculture, waste management, land use change and forestry.

An energy system model and an emissions calculation model were used to develop the scenario by consolidating the results of detailed sectoral analyses, some based on models, into consistent and exhaustive figures for energy demand and greenhouse gas emissions. They are fully compatible with Germany’s Greenhouse Gas Inventories (latest: 2016 National Inventory Report, UBA 2016a).

The descriptions of the measures are taken from the 2017 Projections Report, in which the mitigation effects for individual measures and packages of measures were also modelled. The model system and methodology are explained in more detail in Chapter 5.3. It should be noted that in the buildings and industry and commerce sectors only the direct emissions reductions are shown, for example from fuel savings in this sector. The GHG reduction from electricity savings was modelled for all power-saving measures in the energy sector, with each reduction shown separately (see CTF Table 3 in the Biennial Report, PaM3). To help readers locate the measures in CTF Table 3 in the Biennial Report, the numbering in this chapter matches that in the table.

According to the modelling in the with-measures scenario, the following measures make the greatest contributions to reducing emissions (the figure in brackets is the reduction effect in 2030):

- Putting lignite-fired power stations on standby for reserve capacity: 10 Mt CO₂e;
- Emissions trading: 7.7 Mt CO₂e (13.0 Mt CO₂e);
- Market incentive programme for renewable energy in the buildings sector: 3.9 Mt CO₂e (11.6 Mt CO₂e);
- KfW programme for energy-efficient construction and refurbishment: 2.9 Mt CO₂e (8.7 Mt CO₂e);
- Restricting the use of HFCs in car air conditioning systems in line with EU MAC Directive 2006/40/EC: 3.2 Mt CO₂e (6.1 Mt CO₂e);

¹²⁴ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2014b).

- Energy Conservation Regulation: 3.1 Mt CO₂e (8.0 Mt CO₂e);
- Energy advice for SMEs: 1.5 Mt CO₂e (1.7 Mt CO₂e);
- HFC phase-down prescribed under EU F-Gas Regulation 517/2014 (including Chemicals and Climate Protection Regulation (Chemikalien-Klimaschutzverordnung) and funding under the National Climate Initiative (NKI)): 0.6 Mt CO₂e (5.7 Mt CO₂e);

The main changes made to the portfolio of measures during the 2014–2017 reporting period compared with the Sixth National Communication are as follows:

- Amendment to the Energy Industry Act (Energiewirtschaftsgesetz – EnWG) and placing lignite-fired power plants on standby for reserve capacity only in 2016;
- Amendment to the Combined Heat and Power Act (Gesetz zur Förderung der Kraft-Wärme-Kopplung – KWK-Gesetz) in 2015 and 2016;
- Amendment to the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz – EEG) in 2014 and 2016;
- Introduction of the Energy Efficiency Incentive Programme on 1 January 2016.

4.3.1 Multi-sectoral measures at federal level

Selected measures that have a significant mitigation effect are described in this section, with estimates of the expected reductions. Explanations of the underlying methodology used for the calculations are given in Chapter 4.3.6. The assumptions and methods of calculation for each individual measure are described in detail in Chapters 2.8 and 3.1 of the 2017 Projections Report.

4.3.1.1 EU emissions trading (PaM 1)

Emissions trading has been the main multi-sectoral measure for reducing CO₂ emissions in Germany since 2005. Emissions trading requires operators of power generation plants and energy-intensive industries to surrender CO₂ allowances for their CO₂ emissions during the previous year. It covers CO₂, NO_x, PFC and N₂O gases, and perfluorocarbons from aluminium production. The third phase of EU emissions trading began in early 2013 and runs until 2020. It includes many new rules to harmonise European emissions trading and centralise it in some areas.

There has been only one EU-wide emissions trading budget since 2013. The emissions budget for plants is being reduced by 1.74 % annually from 2010. The result will be a 21 % reduction in the emissions trading sector compared with 2005. According to the decision by the European Council in October 2014, this linear reduction factor will be raised to 2.2 % from 2021 onward compared with the reference value for 2010. The decentralised registry architecture run by the EU Member States until 2012 was replaced by the Union registry. This allows an EU-wide standardised and centralised approach to be used. User accounts are still kept by the individual Member States, but the EU Commission is responsible for development and operation of the registry itself. Further information on this is given in Chapter 3.5.

A market stability reserve will be set up in 2018 and is intended to be ready for use as from 1 January 2019.

Emissions trading for industry primarily affects energy-intensive sectors such as metal production and processing, cement production, and glass and paper making. During the

phase between 2013 and 2020, the scope will be expanded to include additional sectors (primarily the chemical industry and the non-ferrous metals industry), to include the greenhouse gas N₂O in some cases (such as adipic acid and nitric acid production), and to include the perfluorocarbons used in aluminium production.

Emissions allowances for power generation have been auctioned since early 2013. This avoids windfall profits by electricity producers as a result of “pricing in” free allowances. Auctioning takes place throughout the EU using a common platform. However, Germany has exercised the special right to auction allowances through a national platform.

As the third phase begins, free allocation to industrial plants is determined by product-based benchmarks that are uniform throughout the EU. The benchmarks are oriented to the most efficient plants, the top 10 %, in the sector in Europe, thereby rewarding the use of low-CO₂ technologies. Free allocation will be reduced from 80 % to 30 % of the benchmark from 2013 to 2020 in all sectors that are not classified as being at risk for carbon leakage.

Sectors with an increased risk of transfers to third countries receive 100 % free allocation according to the product-based benchmarks.

Uniform rules for monitoring and reporting and for accreditation and verification have also been adopted as part of the harmonisation of emissions trading rules throughout the EU.

All flights taking off and landing in the EU have been included in the European Emissions Trading Scheme for greenhouse gases since 2012. Between 2012 and 2016, however, the reporting and payment requirement was restricted in order to support the efforts of the International Civil Aviation Organization (ICAO) to adopt a global market-based measure (GMBM) for international aviation by 2016 and to introduce it from 2020 onwards.

Essentially only inner-EEA flights, i.e. flights that take off and land on the territory of the European Economic Area, are now subject to the reporting and payment requirement. Non-commercial operators with total annual emissions of less than 1,000 t CO₂ have also been exempt from the reporting and payment requirement since 2013. Following the adoption of the GMBM by ICAO in early October 2016, new arrangements now need to be made for the inclusion of flights to and from the EEA from 2017 onwards.

The German Emissions Trading Authority at the Federal Environment Agency is the national authority responsible for implementation of market-based climate change mitigation instruments in the area of emissions trading, as well as project-based mechanisms under the Kyoto Protocol.

Reduction effect

A reduction in emissions of 9 Mt CO₂e was calculated for emissions trading in the policy scenarios. This involved comparing the GHG emissions under a with-measures scenario with a hypothetical without-measures scenario.

4.3.1.2 Special Energy and Climate Fund, Energy Efficiency Fund and National Climate Initiative (PaM 2)

The Special Energy and Climate Fund was described in the Sixth National Communication. The Fund receives the proceeds from emissions trading. It is used to finance various state funding programmes such as the Energy Efficiency Fund and the National and International Climate Initiatives. Its measures relate to all greenhouse gases. The funding of the Special Energy and Climate Fund has changed during the current reporting period. Due to the income situation of the Special Energy and Climate Fund, the amounts that were originally estimated for subsequent years for the entire Fund had to be corrected downwards as

follows: EUR 232,464,000 in 2013, EUR 202,986,000 in 2014, EUR 213,885,000 in 2015 and EUR 213,885,000 in 2016. In the context of the greenhouse gas projections, however, it is not possible to provide a quantitative assessment of individual projects that are already being funded or are planned in relation to the Energy Efficiency Fund. The impact of the Special Energy and Climate Fund is not directly modelled in the policy scenarios. Instead, only a few of the funding measures supported by the Special Energy and Climate Fund in the end-use sectors private households - electricity (section 4.3.3), industry and trade, commerce and services (section 4.3.4) and buildings (section 4.3.5) are included as supporting measures under the with-measures scenario.

4.3.2 Energy: electricity generation

4.3.2.1 Renewable Energy Sources Act (Gesetz für den Ausbau Erneuerbarer Energien – EEG) (PaM 4)

Since the decisions were taken on the energy transition, the Act has undergone constant development and been adapted to the new requirements and conditions. The amendment of the Act in 2016 defines expansion paths for the most important renewable energy sources. Most of them are to be achieved by means of tendering procedures for funding that are being introduced for biomass systems (with installed capacity above 150 kW), onshore wind turbines and solar systems (with capacity above 750 kW) and offshore wind turbines. The tendering will be carried out by the Bundesnetzagentur (Federal Network Agency), a federal agency that reports to the Ministry for Economic Affairs and Energy.

The expansion path for onshore wind, which also corresponds to the tendering volume, is 2,800 MW p.a. from 2017 to 2019 and 2,900 MW p.a. in 2020 and beyond (gross). The installed capacity of offshore wind turbines is scheduled to rise to 6,500 MW in 2020 and 15,000 MW in 2030. The planned annual gross increase in solar systems is 2,500 MW, with invitations to tender for 600 MW each year starting in 2017. The annual gross increase in biomass systems is projected to be 150 MW initially (2017–2019) and then 200 MW (2020–2022).

Overall, renewables' share in electricity consumption is set to rise from 32 % at present to 40 to 45 % in 2025 and to 55 to 60 % in 2035.

In the German government's 2015 Projections Report, a GHG reduction effect of 147 Mt CO₂e was calculated for the Renewable Energy Sources Act. The reduction was not recalculated in the 2017 Projections Report, and was shown for information purposes with reference to the 2015 Projections Report.

A detailed study of the current state of policies and measures relating to the expansion of renewable energy sources and their effects is provided in the Renewable Energy Progress Report.

4.3.2.2 Promotion of CHP systems (PaM 5)

The Combined Heat and Power Act (Kraft-Wärme-Kopplungsgesetz – KWKG) was amended in late 2015 and late 2016. All in all, the amended Combined Heat and Power Act is the most important measure for promoting CHP plants in Germany. Funding was intended to help achieve national climate targets for high-efficiency CHP plants fired with natural gas. Natural gas CHP plants that replace a coal-fired one receive a bonus. Existing gas-fired CHP plants above 2 MW which are at risk of being shut down will receive limited funding up to 2019. The CHP expansion target has been converted to an increase in net electricity generation from CHP plants to 110 TWh by 2020 and 120 TWh by 2025. Using

CHP plants to supply buildings and neighbourhoods will continue to be promoted by CHP premiums based on output. Funding rates for new and modernised gas CHP plants have been considerably increased overall, with the volume of funding rising from EUR 750 million to EUR 1.5 billion per year. To promote the aims of the Act, small units receive support under the National Climate Initiative based on the Guidelines on Funding for CHP Units up to 20 kW_{el} (Micro-CHP Guidelines), 15 December 2014 version.

To evaluate the support for CHP, a without-measures scenario was created which included the assumption that the amendment of the 2017 CHP Act with the tendering procedure for plants between 1 MW and 50 MW and improved funding for new plants did not exist. The installed capacity of natural gas-based CHP plants then falls by 2.6 GW in 2020.

All in all, emission reduction effects of 2 Mt CO₂e were calculated in this model run.

The evaluation of measures is carried out with reduced natural gas-fired CHP capacity but otherwise with an unchanged power plant fleet. A reduction in emissions of up to 4 Mt CO₂e could come about if emissions outside the electricity sector are avoided on a larger scale (for example by developing new heat sinks). What is important, however, is that the slight reduction of between 2 and 4 Mt CO₂e only occurs in comparison with an unchanged power plant fleet in 2020. CHP already contributes to emissions reductions. From 2014 to 2020, GHG emissions fall by 63 Mt CO₂e, in which CHP of course plays a part.

4.3.2.3 Putting lignite-fired power plants on standby for reserve capacity only (PaM 6)

On 4 November 2015 the federal cabinet decided to put several lignite-fired power plants on standby for reserve capacity only. The shutdown of the relevant power plant units was grounded in Article 13g of the Energy Industry Act (Energiewirtschaftsgesetz – EnWG).

The early mothballing of lignite-fire power plants reduces CO₂ emissions by 10 million tonnes in 2020.

Calculation method

To evaluate the GHG reduction achieved by putting lignite-fired power plants on standby for reserve capacity, a without-measures scenario was generated under which lignite-fired power plants with a net capacity of 2.16 GW were put back into operation in the model. In this context it should be borne in mind that 0.6 GW of lignite-fired condensing power plants were already decommissioned under the with-measures scenario (WMS) in the 2015 Projections Report.

Putting lignite-fired power plants on standby for reserve capacity therefore significantly reduces emissions from this type of power plant. However, the electricity production thus lost must be replaced by other power plants, and at the same time exports fall. Domestically the lost production is mainly taken over by coal-fired power plants, whose emissions rise in the evaluation of measures compared with the WMS. As a result of putting some plants on standby for reserve capacity, electricity generation from lignite-fired plants declines by roughly 20 % by 2020, amounting to 117 TWh in 2020.

4.3.3 Energy: electricity consumption by private households

The effects of the EU Ecodesign Directive, the EU Energy Labelling Regulation, the electricity tax, competitive tendering models (STEP up! electricity), the National Top Runner Initiative (NTRI), the energy-saving meter pilot programme and the advice for low-income households (electricity-saving check) add up to 20.2 TWh of electricity per year in 2020.

The greatest savings result from the Ecodesign Directive, followed by the Energy Labelling Regulation.

4.3.3.1 Minimum energy efficiency standards (EU Ecodesign Directive) (PaM 7)

The Ecodesign Directive 2009/125/EC is the legal framework that specifies minimum efficiency standards for energy-related products in the European internal market. Directive 2009/125/EC was transposed into German law by the 25 November 2011 version of the Energy-Related Products Act (Energieverbrauchsrelevante-Produkte-Gesetz – EVPG). Energy efficiency requirements are defined by EU implementing regulations, which means that they are directly applicable in national law. For further details, please refer to the description of the Ecodesign Directive in the Sixth National Communication.

The following implementing regulations have been adopted since 2014: domestic ovens, hobs and range hoods (Regulation (EU) No 66/2014), transformers (Regulation (EU) No 548/2014), ventilation units (Regulation (EU) No 1253/2014), professional refrigerated storage cabinets (Regulation (EU) 2015/1095), local space heaters (Regulation (EU) 2015/1185, Regulation (EU) 2015/1188), solid fuel boilers (Regulation (EU) 2015/1189), air heating products and cooling products (Regulation (EU) 2016/2281).

Regulations for further product groups are currently in preparation or under examination; see European Commission's Ecodesign Working Plan 2016-2019 of 30 November 2016. Furthermore, existing implementing regulations are revised at regular intervals and the conditions are adjusted in line with technical developments.

Reduction effect

The 2017 policy scenarios attribute electricity savings totalling 30.6 TWh in 2020 to the Ecodesign Directive. Of this, 14.9 TWh is from private households, 4.5 TWh from industry and 11.2 TWh from the trade, commerce and services sector. Emissions reductions from fuel savings in industry and the commerce sector amount to 0.05 Mt CO₂e.

4.3.3.2 Energy label – EU Energy Labelling Regulation (PaM 8)

The new EU Energy Labelling Regulation entered into force on 1 August 2017. It provides for the gradual rescaling of the A+++ label to the A to G label and the introduction of a product database. However, in the 2017 Projections Report, the Energy Consumption Labelling Act (Energieverbrauchskennzeichnungsgesetz – EnVKG) that came into force in Germany on 17 May 2012 was used as the basis for evaluation of the measures; it was described in detail in the Sixth National Communication. The NAPE project to support market surveillance, which was launched on 1 January 2016, is intended to enhance market surveillance to increase the effectiveness of the well-established EU label by identifying test methods, defects and areas where products are subject to particular defects (see flanking instruments). The specific requirements for individual product groups are determined by the EU Commission in supplementary delegated regulations. For the purposes of quantification, all product groups are taken into account for which labelling is mandatory under the delegated regulations as of 31 July 2016.

Reduction effect

In the policy scenarios the effect of the EU energy label with the provisions that have been in force in Germany since May 2012 was calculated as being a reduction of 3 TWh in electricity consumption in private households in 2020.

Calculation method

In the modelling of the GHG reduction effects in the 2017 Projections Report, the minimum standards under the EU Ecodesign Directive were taken into account in the product groups relating to electricity consumption in private households. Because they have similar impacts in the model system, the effects of the Ecodesign Directive and energy label measures were modelled together. A comparison scenario was calculated without the two measures and was compared with the combined effects of the two instruments from 2009 (Ecodesign) and 2010 (energy label). The distribution of the effect across the two measures was then estimated. In this way a savings effect of 14.9 TWh for electricity consumption in private households alone was calculated for the Ecodesign Directive in 2020.

4.3.3.3 National Top Runner Initiative (PaM 9)

Launched in early 2016, the National Top Runner Initiative is addressed equally to manufacturers, retailers and consumers. It is intended to make the benefits of energy-efficient products clear, encourage the development of high-quality products (top runners) and get them to market sooner. Quantification was primarily in the private household sector. Depending on the range of products, in some cases a portion of the effects was allocated to industry and the trade, commerce and services sector.

Reduction effect

Electricity consumption by private households is reduced by 1.1 TWh by this measure in 2020.¹²⁵

4.3.3.4 Competitive tendering models (STEP up! electricity) (PaM 10)

The multi-sectoral instrument of competitive tendering, launched on 1 June 2016 as a measure within the National Action Plan on Energy Efficiency, is a mechanism designed to ensure market-based distribution of funding. The basic idea is to use a tendering mechanism to make the provided capital as cost-effective as possible. A total of EUR 300 million is available for the programme up to the end of 2018. The plan calls for two tendering rounds to be held each year. A constant funding volume of EUR 50 million is assumed for the period after 2018. As a matter of principle, the competitive tendering model is addressed to all players and sectors. The focus of the instrument will initially be directed solely at the electricity sector. Only the effects on electricity consumption are therefore taken into account for quantification. The programme includes background conditions and criteria that allow the stakeholders to submit proposals on specific measures. Specific areas that are known to offer a great deal of potential and to be subject to certain barriers will also be addressed using the closed tendering model. Applications may be submitted for individual projects (measures that the applicant will carry out on its own) and collective projects (third-party implementation of a group of similar measures) by a single organisation known as a project aggregator. The contract is awarded to measures offering the best cost-benefit ratios (euros of funding per kWh saved).

Reduction effect

Electricity savings totalling 1.8 TWh in 2020 were calculated in the model run for the 2017 policy scenarios, attributable one third each to consumption by private households, industry, and the trade, commerce and services sector.

¹²⁵ Quantification was carried out by external consultants in the context of a model calculation. The German government is currently investigating the actual reduction effect as part of an evaluation.

Because of the similarity of the impacts in the system used to model the policy scenarios, the effects of the National Top Runner Initiative and of the competitive tendering models in the STEP up! electricity programme were determined jointly for both measures for the private households sector. To do this, the two measures were first considered as a package and their effects on promoting the spread of efficient technologies were not taken into account in the comparison scenario. The contribution of each measure to the effect was estimated in a second step.

4.3.3.5 Energy-saving meter pilot programme (PaM 11)

In addition to measuring total energy consumption in a private household, building or company, new IT technologies can also measure the energy consumption of individual appliances, systems or subsystems. The energy-saving meter pilot programme, launched in May 2016, makes use of these new IT technologies to do precisely this. It is aimed at service providers that want to carry out pilot projects that will allow their customers to save electricity, natural gas, heat or cooling using “smarter” solutions (smart home/building/industry). A combination of hardware and software is used to digitally record customers’ energy consumption when they use their existing equipment and link their consumption to innovative added-value services to promote efficiency. What all of the projects have in common is that the energy consumption is measured before and after measures are implemented, and the resulting reduction is reported in kilowatt hours and euros. The reduction in energy consumption is then proportionally funded under the programme. Applications are submitted to the Federal Office of Economics and Export (BAFA). Projects are eligible for funding of up to EUR 1 million per project. In the quantification of the measure after the end of the pilot project, there was assumed to be a constant annual programme volume and a higher rate of digital services to promote efficiency based on increased use of smart meters and similar “energy-saving meter” products in households, buildings and industries.

Reduction effect

The pilot programme had just been launched when effects were being assessed in the 2017 policy scenarios, so no information was available about the projects for which applications had been submitted. This measure was therefore not quantified.

4.3.3.6 Advice for low-income households (PaM 12)

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) funded the electricity-saving check PLUS pilot project up to the end of 2015. It provided advice to low-income households in their homes, provided/installed simple energy-saving items free of charge, and offered a grant towards the purchase of a highly energy-efficient refrigerator subject to fulfilment of certain conditions. The new electricity check for local authorities project was launched as part of the National Climate Initiative (NKI) on 1 April 2016. The project builds on the earlier advice scheme for low-income households. The new project now seeks to get electricity checks established at the local authority level over the long term. The following budget funding has been made available for this project: 2016: EUR 7.8 million, 2017/18: EUR 9.8 million each year, 2019: EUR 2.5 million. After that time, the budget will be based on the average programme volume of previous years.

Reduction effect

According to calculations in the 2017 policy scenarios, private households will save 0.15 TWh of electricity in 2020.

4.3.4 Energy: consumption in industry and in the trade, commerce and services sector

In addition to the measures outlined below, the EU Ecodesign Directive as described in section 4.3.3.1, together with the minimum efficiency standards for various product groups defined in the regulations, makes a substantial contribution to improving energy efficiency and hence to the avoidance of greenhouse gas emissions in industry (4.5 TWh) and the trade, commerce and services sector (11.2 TWh).

All in all, the measures implemented in industry produce annual electricity savings amounting to 20.9 TWh in 2020. The electricity savings achieved in the trade, commerce and services sector amount to 25.9 TWh per year in 2020.

4.3.4.1 Special equalisation scheme (BesAR) under the Renewable Energy Sources Act (EEG) (PaM 13)

Under the special equalisation scheme, companies in electricity- and trade-intensive sectors which consume large amounts of electricity are partially exempt from paying the EEG surcharge. The scheme is intended to protect the international competitiveness of companies facing high electricity costs and the associated jobs by limiting additional charges on electricity. When an application is submitted, a review is done to determine whether the company is part of an electricity- and trade-intensive sector. Companies must also prove that their electricity costs account for a large portion of gross value added, must exceed a consumption threshold of 1 GWh/a and show that they have introduced an energy management system. As a result, energy-intensive small and medium-sized enterprises can also take advantage of the scheme. Companies with annual electricity consumption of more than 5 GWh must also show that they are using an energy or environmental management system according to ISO 50001 or EMAS, while companies whose annual electricity consumption is less than 5 GWh are allowed to show that they have an alternative system to improve energy efficiency within the meaning of the Tax Capping Efficiency System Regulation (Spitzenausgleich-Effizienzsystemverordnung). The number of companies or parts of companies in manufacturing industry for which payment of the EEG surcharge has been at least partially waived was 2,006 in 2016, 5 % below the level for 2015 and 3 % lower than in 2014. The number of applicants has stabilised in recent years. The amount of electricity in manufacturing industry for which the EEG surcharge has been partially waived has also decreased since 2014. Waivers for electricity-intensive industry totalled EUR 4.7 billion in 2016.

Indirect reduction effect

The 2017 Projections Report estimates the effect of the special equalisation scheme to be 2.9 TWh of electricity savings in 2020.

4.3.4.2 Funding programme offering grants to promote cross-cutting energy-efficient technologies in SMEs (PaM 14)

The funding programme was reintroduced in amended form as part of the Special Energy and Climate Fund on 10 May 2016. SMEs and large companies can request grants for capital investments in high-efficiency cross-cutting technologies under the programme. The funding distinguishes between capital investments in individual cross-cutting technologies (such as electric motors and drives, pumps, pressurised air systems, systems for heat recovery and the utilisation of waste heat, and insulation in industrial plants) and capital investments for systematic optimisation going beyond the replacement of individual components. The former receive 20-30 % funding up to a volume of EUR 30,000. The latter

are eligible only if the total capital investment is at least EUR 30,000. The amount of the grant is 20 to 30 % of the capital investments eligible for funding, up to a maximum of EUR 150,000 per project.

Reduction effect

In 2020, 1 TWh of electricity is saved in the industry sector with this measure, and 0.1 Mt CO₂e is avoided as a result of fuel savings. In the commerce, trade and services sector the electricity saving is 0.3 TWh, while the quantity of GHG reductions from fuel savings is negligible.

4.3.4.3 Programme funding for energy-efficient and climate-friendly production processes (PaM 15)

Companies in manufacturing industry have been eligible since 2014 for a grant so they can make capital investments to increase the energy efficiency of commercial and industrial production processes. A distinction is made among three areas: conversion of production processes, waste heat utilisation and further improvements to the production process. The programme was launched in 2014 and is part of the Special Energy and Climate Fund. The grant covers up to 20 % of the capital investment costs (additional capital investments) directly related to environmental protection. The maximum grant is limited to EUR 1.5 million for each project. The following requirements must be fulfilled before an application can be submitted: additional capital investments of at least EUR 50,000 and specific final energy savings of at least 5 % while production output remains the same, based on average consumption over the last three years by the system/process being considered, and a reduction in CO₂ emissions of at least 100 kg p.a. for every EUR 100 of additional capital investment. The Federal Ministry for Economic Affairs and Energy has entrusted implementation of the funding programme to the Project Management Agency Karlsruhe.

Reduction effect

The 2017 Projections Report calculates electricity savings of 0.1 TWh in 2020 and 0.2 Mt CO₂e of avoided greenhouse gas emissions from fuel savings in industry as a result of this funding programme.

4.3.4.4 Funding cooling and air conditioning systems under the National Climate Initiative (NKI) (PaM 16)

The programme offers grants for increasing the energy efficiency of existing systems or subsystems and the construction of new high-efficiency plants, along with grants for components such as heat exchangers, cold and heat storage facilities, or coolants having a particularly low global warming potential (GWP). The grants have been awarded as fixed amounts since 1 January 2017; they previously ranged from 15 to 25 % of the net capital investment. They are limited to a maximum of EUR 150,000 per project.

Reduction effect

In the commerce, trade and services sector this measure achieves a reduction in electricity consumption of 0.2 TWh in 2020.

4.3.4.5 Energy efficiency networks (PaM 17)

Companies wanting to set energy efficiency and greenhouse gas reduction goals and learn from one another can join energy efficiency networks. There have previously been some

110 of these networks in Germany, although there is potential for up to 700.¹²⁶ Funding for 40 more energy efficiency networks was approved under the National Climate Initiative in August 2014. The German government's general objective is to establish some 500 voluntary networks by 2020, as decided in the National Action Plan on Energy Efficiency (NAPE). The networks must fulfil uniform minimum requirements, including conducting an energy audit at company level, setting a conservation target at the network level based on individual company targets and taking advantage of the potential for savings that has been identified according to the network target. The networks will have the support of a trained energy advisor. Measures that are implemented will be subject to annual monitoring. It was assumed for the with-measures scenario that the NAPE target will be reached and that a total of 500 networks will be established.

Reduction effect

In the commerce, trade and services sector the energy efficiency networks can reduce electricity consumption by 0.1 TWh and reduce direct GHG emissions from fuel inputs by 0.1 Mt CO_{2e} in 2020. In industry, savings amount to 1.1 TWh of electricity and an additional 0.7 Mt CO_{2e} reduction in greenhouse gas emissions as a result of avoided fuel inputs.

4.3.4.6 Funding guideline for promoting the prevention and utilisation of waste heat (PaM 18)

This guideline, which is an element of the Waste Heat Prevention Campaign, entered into force in 2016. It includes financial support for measures to avoid producing industrial waste heat or to ensure that it is utilised. Funding is in the form of a repayment grant for up to 50 % of the eligible costs under a KfW loan. The programme will fund capital investments in different kinds of technology to encourage modernisation or expansion of existing plants and building new plants if that avoids the production of waste heat or makes it possible to utilise previously unused waste heat more efficiently. This includes internal and external capital investments as well as measures to use waste heat to generate electricity. A total funding volume of EUR 300 million is available up to 2020.

Reduction effect

As a result of fuel savings, this measure avoids 0.1 Mt CO_{2e} in 2020 in the commerce, trade and services sector and 0.5 Mt CO_{2e} in industry. In addition, 0.1 TWh of electricity is saved in industry.

4.3.5 Buildings: heating and cooling

4.3.5.1 CO₂ Building Rehabilitation Programme (PaM 19)

KfW programmes for the energy-efficient construction and modernisation of residential and non-residential buildings are financed with these funding measures by the Federal Ministry for Economic Affairs and Energy via funds from the CO₂ Building Rehabilitation Programme. A total of EUR 2 billion for new funding measures is available in 2017 for the programmes described below.

➔ Energy-Efficient Refurbishment

KfW's Energy-Efficient Refurbishment Programme supports upgrading residential buildings for which the application for planning permission was submitted before 1 February 2002, for the purpose of saving energy. The support is provided through investment grants or low-

¹²⁶ Fraunhofer ISI et al. 2008, p. 180.

interest loans in conjunction with repayment grants. The programme promotes extensive refurbishment to meet the KfW Efficiency House standard and individual measures and combined solutions to improve the energy efficiency of the building itself and/or its services. The amount of the funding depends on the level of efficiency that is achieved. Five categories – EH 55, EH 70, EH 85, EH 100 and EH 115 – have been defined for funding under the KfW Efficiency House scheme. They are determined by the annual primary energy consumption and the transmission heat loss through exposed surfaces of the building based on the reference values of the applicable Energy Conservation Regulation (Energieeinsparverordnung – EnEV).¹²⁷ The EH Monument funding module also promotes the refurbishment of monuments and buildings that are particularly worthy of conservation. Since January 2016 the CO₂ Building Rehabilitation Programme has been supplemented by the Energy Efficiency Incentive Programme (APEE) with its heating and ventilation package funding module, see section 4.3.5.2.

→ Energy-Efficient Construction

The KfW Energy-Efficient Construction programme (known as the Ecological Construction programme until March 2009) is the counterpart to the Energy-Efficient Modernisation programme in the new build sector. It promotes the construction, production or first-time purchase of KfW Efficiency Houses (EH 55, EH 40 or EH 40 Plus) through low-interest loans in combination with a repayment grant.

→ KfW Energy Efficiency Programme – Energy-Efficient Building and Refurbishment (Reducing Energy Costs in the Commercial Building Sector)

The energy-related refurbishment of buildings used for commercial purposes and the construction of new energy-efficient buildings has been supported since 1 July 2015. Funding is provided for refurbishment to reach the KfW Efficiency House standard (EH 70, EH 100, EH Monument) and for building new KfW Efficiency Houses (EH 55 and EH 70) as well as for measures to improve energy efficiency in existing buildings. The federal government offers low-interest loans for this purpose, often in combination with repayment grants. Minimum technical requirements apply, which need to be met in order for funding to be provided.

→ IKK/IKU Energy-Efficient Building and Refurbishment (refurbishment of municipal and social infrastructure)

Since 1 October 2015, buildings used for municipal and social infrastructure are addressed under the IKK/IKU Energy-Efficient Building and Refurbishment programme (until 30 September 2015 known as the IKK/IKU energy-efficient urban refurbishment programmes, limited to refurbishment up to that date). The funding system and requirements for funding resemble those for the KfW Energy Efficiency Programme – Energy-Efficient Building and Refurbishment.

Calculation of the effect

In the policy scenarios, the effect of the individual measures for the buildings sector was assessed in comparison with a without-measures scenario. Under the without-measures scenario it was assumed that the individual measure in question does not exist and cannot therefore have any effect. The effect of the individual measures was estimated from 2016

¹²⁷ A KfW Efficiency House 70 standard is fulfilled, for example, if the building does not consume more than 70 % of the primary energy consumed by an equivalent new build according to the Energy Conservation Regulation. Based solely on the building envelope requirement (Ht'), each value is 15 % higher – for EH 70, for example, a maximum of 85 % of the specific transmission heat coefficient in the Energy Conservation Regulation.

onwards, such that the cumulative annual savings cover the period between 2016 and the year under consideration. Even if a measure pre-dated 2016 (KfW funding programmes, for example), its effects were still not quantified until 2016. In the comparison scenario without KfW programmes, neither energy-efficient new builds nor refurbishment measures in existing buildings were promoted. New builds must be constructed on the basis of the minimum standard required under the Energy Conservation Regulation (see section 4.3.5.4). In the case of refurbishment work, it was assumed that in the absence of funding the refurbishment measures triggered by the KfW programmes are not carried out.

Reduction effect

The calculated direct emissions reductions resulting from fuel savings in the buildings sector amount to 2.9 Mt CO₂e in 2020. There is also a reduction in electricity consumption of 2 TWh.

4.3.5.2 Energy Efficiency Incentive Programme (PaM 20)

The Energy Efficiency Incentive Programme includes four priority areas, which are to some extent integrated into existing funding programmes offered by KfW and the Federal Office for Economic Affairs and Export Control (BAFA under the CO₂ Building Rehabilitation Programme and Market Incentive Programme (MAP):

- Heating package: the heating package funds the replacement of inefficient heating units while simultaneously optimising the entire heating system (for example pipework and radiators).
- Ventilation package: the ventilation package funds the installation of ventilation systems while refurbishment work is carried out on the building envelope.
- Information campaign “Deutschland macht’s effizient”: boosting energy efficiency by motivating all consumer groups (private consumers, local authorities, businesses).
- Market launch of fuel cell heating: since August 2016 the German government has promoted the market launch of innovative fuel cell heating in the 0.25 to 5.0 kW_{el} output class (electrical output) for residential buildings, and since 1 July 2017 also for non-residential buildings (in local authorities and businesses, for example). Grant funding for fuel cell heating is provided via the KfW Energy-Efficient Building and Refurbishment programme – fuel cell grant.

To quantify the GHG reduction effect, annual funding of EUR 165 million was assumed to be available.

Calculation of the effect: in the policy scenarios, the effects of the Energy Efficiency Incentive Programme, Heating Optimisation Programme and National Efficiency Label for existing heating systems were calculated jointly in the model because of the similarity of their impact. The emissions reductions in the scenarios were determined by comparison with a without-measures scenario and with an assumed date of 2016 for the start of the effects, as described above. In the without-measures scenario, the measures triggered by the programmes (especially the replacement of boilers or heat pumps and hydraulic balance) were not implemented.

Reduction effect

The model calculated direct emission reductions in the buildings sector (from fuel savings) amounting to 0.6 Mt CO₂e in 2020, plus a reduction in electricity consumption of 2.6 TWh for the package of three technical measures mentioned above.

4.3.5.3 Market Incentive Programme promoting the use of renewable energy technology (PaM 21)

The funding measures under the Market Incentive Programme (MAP) promote the use of systems using renewable energy sources for heating and cooling and certain heat storage facilities and local heating networks for both residential and non-residential buildings. Eligibility is mainly restricted to systems in existing buildings, with funding for systems in new buildings provided only in exceptional cases involving a particular level of innovation. The details of MAP funding are given in the guidelines on promoting the use of renewable energy technology in the heat market (Richtlinien zur Förderung von Massnahmen zur Nutzung erneuerbarer Energien im Wärmemarkt) published on 11 March 2015. Funding under the programme is divided into two parts. The Federal Office for Economic Affairs and Export Control (BAFA) offers investment grants for systems in the lower output range (rated useful heat up to 100 kW). Solar thermal systems, biomass systems and efficient heat pumps are eligible for the grants. For larger systems, the federal government offers grants for early partial repayment of low-interest loans under the KfW Renewable Energies programme, premium option. Large solar thermal systems, biomass heating (and power) plants, large, efficient heat pumps, biogas piping, deep geothermal systems, local heating networks for heat from renewable energy sources and large heat storage facilities for renewable heat are all eligible under this part of the programme. MAP funding has been enhanced by the introduction of the Energy Efficiency Incentive Programme (APEE), see section 4.3.5.2, which offers additional funding for replacing a heating system (heating package).

Budget funds of some EUR 222 million and an additional EUR 87 million from the Special Energy and Climate Fund are available for the Market Incentive Programme in 2017.

Calculation of the effect

The emissions reductions in the scenarios were determined by comparison with a without-measures scenario and with an assumed date of 2016 for the start of the effects. In the without-measures scenario there was no MAP funding for renewable heat generators. It was assumed that the investment in renewable heat systems triggered by the Market Incentive Programme does not happen.

Reduction effect

The model calculates direct GHG reductions from fuel savings amounting to 3.9 Mt CO_{2e} and 0.5 TWh of electricity savings in 2020.

4.3.5.4 Energy Conservation Regulation 2014 (PaM 22)

The Energy Conservation Regulation (Energieeinsparverordnung – EnEV), a regulatory measure based on the Energy Conservation Act (Energieeinsparungsgesetz – EnEG), governs minimum energy requirements for new builds and for existing buildings undergoing major refurbishment. The regulatory requirements apply to both residential and non-residential buildings if they are regularly heated or cooled with the use of energy. The main features of the Energy Conservation Regulation were described in detail in the Sixth National Communication. The most recent amendment of the regulation entered into force on 1 May 2014, under which stricter requirements for the primary energy demand for new builds were imposed with effect from 2016. The maximum admissible primary energy demand was reduced by 25 % compared with the 2009 Energy Conservation Regulation, and the requirements for the energy performance of the building envelope were made 20 % stricter on average. The requirements for refurbishing existing buildings were retained. Furthermore, since 2015 old boilers that use liquid or gaseous fuels must be removed. This ruling applies to boilers that were installed before 1 January 1985. Boilers installed after this date are subject to the regulation after 30 years of operation. Condensing boilers and low-temperature boilers are entirely exempted from the regulation. There are also exceptions for certain owner-occupied detached or semi-detached houses.

Calculation of the effect

In the policy scenarios in the 2017 Projections Report the emissions reductions were determined by comparison with a without-measures scenario and with an assumed date of 2016 for the start of the effects, as described in section 3.2.1.25. In the without-measures scenario the minimum requirements for new builds were frozen at the level of the 2014 Energy Conservation Regulation. The conditional obligation to refurbish buildings did not apply, but it was assumed that energy-efficient modernisation work in compliance with the Energy Conservation Regulation is carried out in about half of all cases where refurbishment takes place. With regard to the obligations to upgrade boilers it was assumed that boilers over 30 years old are replaced only half as often as under the requirements of the Energy Conservation Regulation.

Reduction effect

Direct emission reductions of 3.1 Mt CO_{2e} are achieved in the model in 2020 as a result of fuel savings, and 0.9 TWh of electricity is saved.

4.3.5.5 National Efficiency Label for heating systems (PaM 23)

The goal of the labelling measure is to motivate building owners to replace older, less-efficient heating systems, thereby increasing the replacement rate. Heating installers, chimney-sweeps (who are responsible for inspecting heating systems in Germany) and certain energy advisors have had the authority to affix the energy label to appliances since 2016. Since 2017, district chimney sweeps have been required to issue the energy label for boilers more than 15 years old after completing their regular inspection. The labels are issued progressively based on the age of the boiler. The energy label assigns the boiler to a certain energy class and informs the owner about reducing energy costs and about the availability of more extensive advisory services (for example provided by the Federation of

German Consumer Organisations – vzbv – or BAFA as part of its on-site energy advice scheme) or funding sources.

Reduction effect

See above, Energy Efficiency Incentive Programme. The reduction effect was calculated jointly for the three measures: Energy Efficiency Incentive Programme, Heating Optimisation Programme and National Efficiency Label for existing heating systems.

4.3.5.6 Energy performance certificate (PaM 24)

The energy performance certificate is an important measure for providing information in the buildings sector. As an integral part of the Energy Conservation Regulation, it comes under regulatory law. The energy performance certificate provides information about a building's energy efficiency and must be given to potential buyers or tenants. The energy performance certificate can show details of either demand or consumption.

To increase the transparency of the property market, the new provisions that entered into force on 1 May 2014 make energy performance certificates more informative. They also impose additional requirements and clarify the requirements for issuing and using energy performance certificates. New energy performance certificates for residential buildings have also included information about energy efficiency classes since 1 May 2014; they must be provided to prospective tenants or purchasers no later than during viewings. The buyer or new tenant receives a copy of the document after the contract is signed. A requirement to include certain information on energy from an energy performance certificate in real estate advertisements for sales or rentals, if the certificate exists at the time of publication, was introduced on 1 May 2014.

Reduction effect

In the 2017 Projections Report no separate GHG reduction figure was calculated for this information instrument because it is difficult to distinguish it from the effect of regulatory or funding measures.

4.3.5.7 Energy advice for residential buildings (on-site advice, individual refurbishment roadmap) (PaM 25)

Under the energy advice scheme for residential buildings (on-site advice), financial support is provided for energy advice reports (including refurbishment plans) supplied by qualified experts in residential buildings. The reports assist building owners in taking decisions on refurbishment and are intended to help ensure that sections of individual buildings are refurbished in a way that enables them to ultimately fulfil the requirements for nearly climate-neutral existing buildings by 2050. For example, specific measures are recommended which together will result in an Efficiency House that is eligible for funding under KfW's Energy-Efficient Refurbishment programme, or which support phased upgrades, such as in an individual refurbishment roadmap. Such refurbishment roadmaps provide guidance and transparency about the best possible sequence of modernisation work to improve energy efficiency from technical and economic viewpoints, taking into account the building owner's individual situation, such as age of the building or available funds.

Appropriate analyses of the economic efficiency of the proposed refurbishment measures must also be included in the report. A list of energy-efficiency experts for federal funding programmes in the residential buildings sector has been available as an online database since late 2011 to ensure the quality of energy advice and the planning of KfW-funded

Efficiency Houses and provide support while they are being built. Experts have to fulfil strict requirements in order to qualify. Regular continuous professional development is a prerequisite for being listed as an expert in the database. Using the list of experts or the database has been required for KfW programmes since 1 June 2014.

Reduction effect

In the 2017 Projections Report no separate GHG reduction figure was calculated for this information instrument because it is difficult to distinguish it from the effect of regulatory or funding measures.

4.3.6 Transport

The following measures to reduce greenhouse gases in the transport sector were included in the with-measures scenario in the 2017 Projections Report. They were approved before 31 July 2016 and have therefore entered into force or will soon enter into force.

4.3.6.1 CO₂ emissions standards for cars (PaM 26)

The arrangements for final establishment of the basis for calculating the defined emission target in 2020 were agreed with the introduction of the Worldwide Harmonised Light Vehicles Test Procedure (WLTP) into the European type approval legislation. At present the target value for 2020 or 2021 is still based on the New European Driving Cycle (NEDC). However, currently only WLTP values are measured, so these will be converted into NEDC values using a specially developed correlation tool. The basis is thus established for the uniform enforcement throughout Europe of EU Regulation 443/2009 on CO₂ emissions limits for newly registered passenger cars.

Reduction effect

No GHG reduction effect was determined for this measure in the Projections Report.

4.3.6.2 CO₂ emissions standards for light commercial vehicles (PaM 27)

Regulation (EU) No 510/2011 introduced an average specific CO₂ emissions target of 175 g CO₂/km for newly registered light commercial vehicles in the EU. This emissions target was set to be achieved in stages by 2017. The CO₂ emissions target specified for 2020 is 147 g CO₂/km, but a process to determine the final form of the Regulation for that year is currently in progress because of the introduction of the WLTP, although this does not have any impact on the target value stated in the Regulation. The implementing regulations on CO₂ monitoring under the WLTP have entered into force. Further development of the technology during the period beyond 2020 is assumed.

Reduction effect

No GHG reduction effect was determined for this measure in the Projections Report.

4.3.6.3 Expansion of the HGV toll (PaM 28)

A toll has been charged for heavy goods vehicles with a maximum permissible gross laden weight greater than 12 tonnes using the Autobahn motorway system since 2005. The new Act on Levying Mileage-Based Charges for the Use of Federal Motorways and Highways (Gesetz über die Erhebung von streckenbezogenen Gebühren für die Benutzung von Bundesautobahnen und Bundesstrassen) entered into force on 19 July 2011. It replaced the Autobahn Toll Act for Heavy Goods Vehicles. The HGV toll was extended in two stages, on 1 August 2012 and 1 July 2015, to include about 2,300 km of four-lane federal highways.

On 1 October 2015 the weight limit was reduced to 7.5 tonnes maximum permissible gross laden weight and the number of axle classes was increased from two to four. As of 1 July 2018, the HGV toll is due to apply to all 40,000 km of roads built and maintained by the federal government. Depending on pollutant class, tolls are currently 8.1 cents/km to 16.4 cents/km for vehicles with two axles; 11.3 cents/km to 19.6 cents/km for those with three axles; 11.7 cents/km to 20.0 cents/km for those with four axles and 13.5 cents/km to 21.8 cents/km for those with five or more axles.

The external costs of air pollution have been incorporated since 1 January 2015 in line with Directive 1999/62/EC. The allocation of noise costs will be examined by the end of 2017.

Reduction effect

The 2017 Projections Report calculated the direct emission reductions in 2020 as being 0.1 Mt CO_{2e}. The assumptions and method used for the simulation are described in section 3.1.2 of the Projections Report.

4.3.6.4 Promotion of electric mobility (PaM 29)

The German government and industry came together in the National Platform for Electric Mobility (NPE) to define the goal of developing Germany into a lead market for and lead supplier of electric mobility. The goal is to have one million electric vehicles in use by 2020, rising to six million by 2030.

A purchase subsidy of EUR 4,000 for fully electric vehicles and EUR 3,000 for hybrids is being paid, half of which is financed by the automotive industry and half by the federal government. Total funding is limited to EUR 1.2 billion (EUR 600 million from the government and EUR 600 million from the automotive industry), and the programme, which is based on the first come, first served principle and began with a decision by the government in May 2016, will end no later than 2019. The upper limit of funding for each basic model is EUR 60,000 (list price). The half of the funding from the government is conditional on receiving match funding from the manufacturer. The share of electric vehicles to be purchased by the government to carry out its business is also to be increased to at least 20 %. The following new provisions apply from 1 January 2017 until 31 December 2020: under the German Income Tax Act (Einkommensteuergesetz), benefits granted by an employer for charging an electric vehicle or hybrid electric vehicle on the employer's premises with a company-owned charging facility that is temporarily put to private use are exempt from tax. Employers also have the option to reduce the level of withholding tax for an employee's wage to a flat rate of 25 % on the benefits of monetary value from the assignment of a charging facility free of charge or at a reduced price and for subsidies for an employee's expenditure on purchasing and using a charging facility.

The Charging Point Regulation (Ladesäulenverordnung) creates binding standards for plugs for the charging infrastructure used for electric mobility and entered into force on 17 March 2016. Operators of charging infrastructure and final consumers are to be treated equally under the Electricity Market Act (Strommarktgesetz). This will create legal clarity with regard to operators' energy-related obligations. Rapid charging infrastructure for electric vehicles is also scheduled to be installed on 400 motorways service stations – if possible in 2017. As many as 600 additional fast charging points are also scheduled to be installed between 2015 and 2017 as part of the SLAM – Fast-charging network for axes and metropolises – research project. This has now largely been completed.

The federal government is providing €300 million for the 2017–2020 period under a funding programme to expand publicly-accessible infrastructure for charging electric vehicles throughout Germany.

Further development and testing of electric drives in utility vehicles

The range of applications for electric drives in heavy goods vehicles has previously been restricted by the limited performance of batteries and the associated reduced range of vehicles. The use of electric drives in the category of up to 7.5 tonnes maximum permissible gross laden weight in parcel delivery vehicles, for example, appears promising. At least one manufacturer is planning to use electric drives in large vehicles up to 26 tonnes maximum permissible gross laden weight by 2020. The combination of fast-charging batteries and overhead contact line sections for recharging batteries while driving will considerably expand the possibilities for using electric drives. This combination of HGVs powered by electric batteries and an overhead contact line section will be tested under actual conditions during a field trial.

Reduction effect

The 2017 Projections Report calculated a GHG reduction of 0.5 Mt CO₂e in 2020 for various measures promoting electric mobility. If indirect emissions are taken into account (for example as a result of emissions being transferred to the electricity sector when electricity is used as a fuel), the GHG reduction is 0.2 Mt CO₂e.

4.3.6.5 Strengthening public transport (PaM 30)

The Länder are responsible for local public transport. The federal government promotes the strengthening of public transport in the Länder by providing regionalisation funds, the main focus of which is local rail transport. Based on the agreement by the government and the Länder to increase regionalisation funds to EUR 8.2 billion in 2016 and to raise the rate at which funding will increase each year to 1.8 % up to and including 2031, it was assumed that by 2031 the federal government will have provided a total of EUR 15.6 billion more than was previously available.

To make public transport even more attractive, the federal government is also supporting the nationwide introduction of e-ticketing along with an improved information system for passengers, contributing EUR 16 million for the 2016–2018 period.

Reduction effect

This measure reduces GHG emissions by 0.1 Mt CO₂e in 2020.

4.3.6.6 Promoting alternative drive systems in public transport (PaM 31)

Within the framework of the funding guidelines on electric mobility applied by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Ministry of Transport and Digital Infrastructure (BMVI), the German government is funding many projects to promote the further technological development and/or procurement of electric and hybrid buses in an effort to help low-emission and emission-free vehicles become established on the market sooner. The purchase of externally chargeable plug-in hybrid buses is being funded under the new funding guideline published by BMUB (2015–2017 period). The first requests for funding have already been approved. BMVI's funding guidelines on electric mobility emphasise projects to promote the further technical improvement or procurement of fully-electric buses and to expand the necessary charging infrastructure. Requests for funding have already been approved in this case, too.

Reduction effect

The effect of this flanking measure was not determined separately in the 2017 Projections Report.

4.3.6.7 Promoting rail transport infrastructure (PaM 32)

The immediate action programme II on seaport hinterland transport includes measures to improve the federal government's rail infrastructure which can be implemented in the short term and also increase capacities for seaport hinterland transport. Efforts will focus on smaller-scale measures that can be implemented quickly before the end of 2020.

Reduction effect

The direct emission reductions in 2020 amount to 0.1 Mt CO₂e.

4.3.6.8 International maritime transport

Within the International Maritime Organization (IMO), Germany is one of the main initiators in the development of rules on air quality and the reduction of greenhouse gases. Under the leadership of the Federal Ministry of Transport and Digital Infrastructure (BMVI), the German delegation comprises experts from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), the Federal Environment Agency (UBA) and other specialised organisations (such as the Federal Maritime and Hydrographic Agency (BSH) and DNV GL). The Marine Environmental Protection Committee (MEPC) is responsible for the subject of greenhouse gas emissions at IMO.

By successfully introducing an Energy Efficiency Design Index (EEDI) and a binding Ship Energy Efficiency Management Plan (SEEMP) for new ships, IMO has adopted the first effective instruments that improve energy efficiency and reduce CO₂ emissions in shipping.

Germany is currently engaged in drafting an IMO roadmap for developing an emissions reduction strategy for shipping, according to which a medium-term reduction target for shipping is to be adopted by 2018 and a long-term target by 2023. In this, Germany is not only working with European partners but is also consulting closely with representatives of the Small Island Developing States (SIDS) that are most seriously affected by climate change, leading to the joint submission of numerous proposals for discussion to the MEPC on how next to proceed. The Paris Agreement brought about a noticeable relaxation in the political stalemate at IMO between developing and emerging countries on the one hand and industrialised nations on the other. The proposals put forward for negotiation on behalf of the industry associations, too, are now mostly constructive.

IMO has also adopted a global system to collect data on ships' fuel consumption and CO₂ emissions, which will provide the foundation for decisions on further technical or operational measures. If necessary, the European system of monitoring, reporting and verification (MRV) of relevant data on maritime transport will be adapted to IMO's global system.

Reduction effect

This measure relates to emissions sources outside Germany, and was not modelled in the 2017 Projections Report.

4.3.6.9 International aviation

The International Civil Aviation Organization (ICAO) considers technical environmental aspects within its Committee on Aviation Environmental Protection (CAEP), which runs a number of different working groups. To deal with greenhouse gas issues, ICAO had

previously also established various high-ranking working groups, such as the Group on International Aviation and Climate Change (GIACC) in 2008, to resolve important political issues related to the introduction of climate mitigation instruments.

In January 2012 aviation was brought into the EU Emissions Trading Scheme, in accordance with EU Directive 2008/101/EC, but enforcement for non-European flights was suspended for a set period. EU Member States thus waived sanctions for non-fulfilment of reporting and payment requirements from 2010 to 2016 for all flights between European and third countries. Requirements for flights within the EEA were not affected.

The purpose of restricting the scope of application was to support ICAO's efforts to adopt a global market-based measure (GMBM) for international aviation by 2016 and to introduce it from 2020 onwards. ICAO finally adopted the GMBM in October 2016. As an ICAO member, Germany has committed itself to producing an environmentally effective, competition-neutral and lastingly robust measure. Political support was backed up by the specific technical work carried out by the CAEP Global Market Based Measure Technical Task Force (GMTF).

Reduction effect

This measure relates to emissions sources outside Germany, and was therefore not modelled in the 2017 Projections Report.

4.3.7 Industry: process-related emissions

4.3.7.1 EU emissions trading (PaM 1)

A series of N₂O point sources (adipic and nitric acid production, production of glyoxal and glyoxylic acid) was included in the European Emissions Trading Scheme in early 2013 (see section 4.3.1.1).

Reduction effect

Please refer to the 2015 Projections Report for an evaluation of measures (including N₂O emissions from nitric acid and adipic acid production under the EU Emissions Trading Scheme). No relevant change in the quantification is to be expected, so the impact of the measure was not re-calculated in the 2017 Projections Report.

4.3.8 Industry: process-related emissions of fluorinated greenhouse gases (PaM 45)

4.3.8.1 Implementation of EU Regulation 517/2014

Calculation of the effect

Since 2015, emissions inventories have been required to comply with the 2006 IPCC Guidelines, which meant that the number of fluorinated greenhouse gases (F-gases) to be taken into account was expanded to include an additional six hydrofluorocarbons (HFCs), two perfluorocarbons (PFCs) and nitrogen trifluoride (NF₃). This change also led to the use of global warming potentials (GWPs) from the 4th IPCC Assessment Report (AR4) to convert emissions of the various F-gases into CO₂ equivalents.

Under the with-measures scenario (WMS) in the 2017 Projections Report, Regulation (EU) No 517/2014 on fluorinated greenhouse gases (F-Gases Regulation), which entered into force in 2014, brought about the greatest change. In addition to the measures to reduce emissions of fluorinated greenhouse gases described in the Sixth National Communication, the WMS in the Projections Report also took account of the following measures:

- Gradual restriction of the quantity of HFCs available on the EU market by 2030 to 21 % of the total quantity placed on the market in the Union during the period from 2009 to 2012, as set out in Regulation (EU) No 517/2014;
- Bans on the placing on the market of certain products and equipment that contain fluorinated greenhouse gases, as set out in Regulation (EU) No 517/2014: fire protection equipment (HFC-23), certain refrigeration and air-conditioning equipment, foams (HFCs) and technical aerosols (HFCs);
- Ban on the use of SF₆ in all magnesium die-casting in accordance with Regulation (EU) No 517/2014;
- Maintenance obligation/leak checks for equipment containing fluorinated greenhouse gases in quantities of five tonnes of CO₂ equivalent or more in accordance with Regulation (EU) No 517/2014.

Reduction effect

In total, the policy scenarios for the measures to reduce process emissions in industry were calculated to produce an effect of 4.7 Mt CO₂e in 2020. Implementation of Regulation (EU) No 517/2014 contributes 1.2 Mt CO₂e to this (PaM 33 and 34), the inclusion of CFCs from primary aluminium in the EU Emissions Trading Scheme leads to a reduction of 0.3 Mt CO₂e in 2020 and implementation of EU Directive 2006/40 relating to emissions from air-conditioning systems in motor vehicles leads to a reduction of a further 3.2 Mt CO₂e (PaM 35).

4.3.9 Waste management

4.3.9.1 Amendment to the Technical Instructions on Air Quality Control (TA Luft), emission-reduction measures in digestion plants (PaM36)

According to this planned regulation, which is currently the subject of consultation within the German government, the aerobic treatment of digestion residues, and especially their removal from the digestion tank and aeration, must take place in an enclosed space. Any exhaust gases must be scrubbed. Emission-reduction measures such as those currently required in the draft Technical Instructions on Air Quality Control result in a reduction in greenhouse gas emissions from composting and anaerobic digestion. In future, improved process management and monitoring will have the particular purpose of reducing the amount of methane generated in the plants and thus lead to a reduction in emissions. Furthermore, the use of biogas generated in the digestion process to produce energy serves as a substitute for fossil fuels, thus avoiding greenhouse gas emissions. Therefore despite the increase in volumes of separately collected biowaste, emissions of greenhouse gases from composting and anaerobic digestion at biogas plants will decrease. However, for reporting reasons this reduction is not attributed to waste management.

Reduction effect

For the purposes of modelling it was assumed that the required measures to collect and scrub the exhaust gas produced during removal and treatment of the digestion residues will affect the methane emissions only. According to an expert estimate by Öko-Institut, it is realistic to expect methane emissions from anaerobic digestion plants to be reduced by up to 90 %.¹²⁸ A reduction of 80 % was assumed for the modelling, and it was assumed that

¹²⁸ See Dehoust et al. (2010), for example.

the improvements would begin in 2018 and be completed in 2025. The emission factor for methane emissions from anaerobic digestion estimated in Federal Environment Agency 2016, of 2.80 kg methane per Mg biowaste, is thereby reduced to an average of 2.52 kg methane per Mg biowaste in 2020. GHG emissions in 2020 are reduced by 0.1 Mt CO₂e.

4.3.9.2 Landfill aeration (PaM 37)

Landfill aeration is a highly effective emission reduction measure, especially for landfill sites where declining gas formation and diminishing methane content mean that there are only very limited opportunities for using the landfill gas to generate energy. Atmospheric oxygen is introduced into the landfill body by low-pressure or high-pressure aeration, and the remaining biodegradable constituents of the landfill are oxidised by microbial activity. Instead of being converted into methane, which is what happens during anaerobic degradation, the biogenic carbon in the waste is converted under aerobic conditions into carbon dioxide, which is biogenic in origin and therefore greenhouse-neutral. The potential for methane formation and hence possible methane emissions from the landfill site is reduced by up to 90 %.

Since 2013 landfill aeration has been promoted with funds from the National Climate Initiative. Under the Climate Action Programme 2020 this support was expanded, and the deadlines for applications were initially extended until 2018.

Calculation of the effect

The assumptions and assessment method are explained in the 2017 Projections Report, section 3.1.14. The GHG reduction effect is estimated to be 0.07 Mt CO₂e in 2020.

4.3.9.3 Strengthening recycling through the Packaging Act and the Commercial Waste Regulation (PaM 38)

The provisions of the 2017 Packaging Act (Verpackungsgesetz) and the 2017 Commercial Waste Regulation (Gewerbeabfallverordnung) will lead to an increasing rate of recovery of secondary raw materials from waste, with preference being given to recycling or otherwise using them to generate energy. As a result of the substitution of primary raw materials, this leads to the avoidance of greenhouse gas emissions compared with the extraction and use of primary raw materials. The new version of the Commercial Waste Regulation has been in force since 1 August 2017, and the amended Packaging Act will enter into force on 1 January 2019.

Reduction effect

It is not possible to account for the avoidance in the waste sector because the effects arising from the legal provisions are not yet quantifiable and, statistically, the reductions are attributed to the National Greenhouse Gas Inventories of the industrial sectors that make use of the recycled materials.

4.3.10 Agriculture

4.3.10.1 EU Common Agricultural Policy (PaM 39)

The economic and legal environment for agriculture is primarily determined by the market trend, the EU's Common Agricultural Policy (CAP) and national regulatory law. Decisions on resource and energy policy also play a part. They influence the extent to which material and energy from crops and residues in agriculture are put to use. This has a tangible impact on land use and on emissions in this sector. The central element of Germany's CAP

implementation is the system of direct payments to farmers being fully decoupled from production. Germany does not use the additional options under the CAP, which have been available since 2015, to make direct payments coupled to production, for example for suckler cows and ewes, for example.

The reform of the CAP approved in December 2013, which applies to the 2014–2020 financing period, introduced the “greening” of direct payments under the first pillar of the CAP. Greening makes 30 % of direct payments contingent on three requirements: maintaining permanent grassland, diversifying crops and dedicating 5 % of arable land to ecologically beneficial elements (“ecological focus areas”).

Greening has been used in Germany since 1 January 2015. Maintaining permanent grassland is the greening requirement that has the most direct effect on greenhouse gas emissions by agriculture. Its effects are reported in the LULUCF source category (see below). The other two greening requirements (for example as a result of growing more nitrogen-fixing crops and thus sequestering atmospheric nitrogen) may also lead to emissions reductions in agriculture, albeit to a lesser extent. The creation of ecological focus areas is primarily intended to foster biodiversity.

In addition to direct payments under the first pillar, the Länder development programmes for developing rural areas are co-financed with funds from the European Agricultural Fund for Rural Development (EAFRD) under the second pillar of the CAP. Under EAFRD, the promotion of agri-environment-climate measures (AECMs) and of organic farming is a key instrument in achieving environmental and climate targets. Relevant measures to reduce direct GHG emissions in the domestic agriculture source category include reducing the use of mineral nitrogen fertiliser as a result of increased organic farming or the extensification and maintenance of grassland.

Reduction effect

The effects of the CAP regulations on greenhouse gas emissions in Germany were not modelled in the Projections Report.

4.3.10.2 Expansion of organic farming (PaM 40)

The aim of the German Sustainable Development Strategy (2017) is for 20 % of all agricultural land to be organically farmed. Both conversion to and maintenance of organic agriculture can be promoted in accordance with the Joint Task for the Improvement of Agricultural Structures and Coastal Protection (GAK) framework plan. The level of payments was significantly raised in the 2015 GAK framework plan and was unchanged in 2016. Under the national framework plan within GAK, funding per hectare for conversion to and maintenance of organic farming was raised by about 20 % from 2014 and 2015 (when comparing 2013 with 2015). The Federal Ministry of Food and Agriculture introduced a future strategy for organic farming on 15 February 2017 in order to speed up achievement of the 20 % target for the amount of land cultivated using organic production methods as defined in the German Sustainable Development Strategy. Increasing the amount of organically farmed land will help to reduce nitrous oxide emissions from mineral fertiliser, primarily because organic production methods avoid the use of nitrogen mineral fertiliser.

Reduction effect

The 2017 Projections Report calculated the GHG avoidance effect as 0.034 Mt CO₂e in 2020, assuming the target for the amount of land under organic cultivation in 2020 is achieved. A scenario in which the area of land cultivated organically increases at the same

rate as the average for 2010 to 2015 was used as a comparison. Information on the calculation method and assumptions is given in section 3.1.12.

4.3.10.3 Increasing the use of farm manure in biogas plants (PaM 41)

The Renewable Energy Sources Act (EEG) promotes electricity generation from renewable energy sources, so it was assumed that the use of farm manure in biogas power plants will increase to 30 % of all farm manure produced by 2025. It was also assumed that that percentage will remain constant up to 2035. It was assumed that biogas plants fired with renewable raw materials (energy crops such as silo maize) will no longer be in use after a 20-year service life. As a result, the amount of plant-based digestion substrate will decline after 2025. It was further assumed that the portion of digestion residue storage units without a gas-tight cover will remain at the 2015 level. Increased co-digestion of farm manure in biogas power plants will reduce methane and nitrous oxide emissions from storing the manure.

Reduction effect

In the 2017 Projections Report, no quantifiable reduction effect is attributed to this measure until 2025.

4.3.10.4 Amendment to the Fertiliser Application Regulation (PaM 42)

The amendment to the Fertiliser Application Regulation (Düngeverordnung) entered into force at the end of May 2017, thus putting key provisions of the EU Nitrates Directive into effect in Germany. Many aspects of the Fertiliser Application Regulation influence the management of nutrients, particularly farm manure. The new regulations now also include manure of plant origin (digestion residues from biogas plants) in the permitted field application limit for organic fertilisers of 170 kg N/ha, and mandatory fertiliser planning according to specific instructions has been introduced. In addition, for the first time provisions have also been included to reduce atmospheric nitrogen losses (obligation to incorporate manures and urea on uncultivated arable land within four hours), and from 2020 the permissible gross nitrogen balance surplus is reduced from previously 60 to 50 kg N/ha on a three-year average. In order to target regional pollution situations more specifically, the Länder now have the option of introducing further measures such as shorter incorporation times, longer closed periods for applying fertiliser and lower permissible nutrient surpluses in areas with high nitrate inputs and high phosphorus loads in surface waters. These measures are expected to lead to more energy- and resource-efficient use of organic and mineral fertilisers and a resulting decrease in the nitrogen surplus. To lower emissions of reactive nitrogen in the agriculture sector, efforts are being made to achieve a considerable reduction in nitrogen surpluses as part of efforts to use fertiliser more efficiently and improve utilisation of the fertilising effect of organic fertilisers. The nitrogen surplus in the total N balance is to be reduced to 70 kg N/ha on a five-year average by 2030, with a further significant reduction by 2050. In the 2017 Projections Report it was assumed that increasing nitrogen uptake and limiting N balances reduces the use of nitrogen mineral fertiliser by approximately 20 % compared with 2012. This reduces nitrous oxide emissions from fertiliser use.

Reduction effect

This measure reduces GHG emissions by 2.2 Mt CO₂e in 2020.

4.3.10.5 NEC Directive (PaM 43)

A 29 % reduction in ammonia emissions by 2030 compared with 2005 levels is specified in the new National Emissions Ceilings (NEC) Directive (2016/2284/EU), which entered into force on 31 December 2016 replacing earlier legislation (Directive 2001/81/EC). Some measures in the above-mentioned amendment to the Fertiliser Application Regulation contribute to this reduction (provisions on prompt incorporation of manures on uncultivated arable land, low-emission ground-level application of slurry and the use of urease inhibitors in mineral urea-based fertilisers). Under the NEC Directive, Germany is required to submit a National Air Pollution Control Programme to the Commission by 1 April 2019 describing measures suited to achieving the reduction targets. The measures to reduce the atmospheric pollutant ammonia have the indirect effect of reducing CO₂ and N₂O.

Reduction effect

The NEC Directive results in GHG emissions being reduced by 0.4 Mt CO₂e in 2020.

4.3.11 Forestry and land use change

4.3.11.1 Reduced land take for settlement and transport (PaM 44)

The German Sustainable Development Strategy contains the stated goal of limiting additional land take for settlement and transport to less than 30 ha per day up to 2030 by means of sustainable land management.

Reduction effect

A total of 0.5 Mt CO₂e can be avoided in 2020. This figure was established in the 2017 Projections Report. It was assumed that land take in the LULUCF sector decreases and that there is permanent grassland conservation under the with-measures scenario. The effects of the individual measures under the with-measures scenario were assessed by comparison with a without-measures scenario, in which, as is currently the case, approximately 130 ha per day is converted to settlement and transport area from other types of land use.

4.3.11.2 Maintaining permanent grassland (PaM 45)

The Climate Action Programme 2020 includes conservation of permanent grassland. Implementation of the greening requirements introduced during the CAP reform is being pursued with particular zeal in Germany. According to the provision that applies up to 2020, farms that receive direct payments and are subject to greening requirements may not plough or convert permanent grassland in Special Areas of Conservation where such grassland was in existence on 1 January 2015. Other permanent grassland that is not classified as environmentally sensitive may generally be converted only if an official permit has been granted, subject to documentation of a replacement area of equal size on which new permanent grassland must be established. The conservation of permanent grassland is also supported by provisions in several Länder. It can be assumed that the regulations to be applied under the reform of the CAP after 2020 will as a general principle also include provisions to protect permanent grassland. The assumption is therefore that the existing protection of permanent grassland will be continued beyond the period of validity of the current CAP.

Reduction effect

If the areas of permanent grassland are maintained at the level of 2014, greenhouse gas emissions in 2020 are reduced by 0.8 Mt CO₂e. For the purposes of comparison, a scenario was used in which permanent grassland continues to decline in line with the trend from 2000 to 2014.

4.3.11.3 Funding programmes for forestry (PaM 46)

The following policies and measures, among others, are listed in the Climate Action Plan 2050:

- In the context of the Joint Task for the Improvement of Agricultural Structures and Coastal Protection, German government funds are being used to support forest conversion measures that will also take climate change into account. The measures are aimed at forest adaptation based on growing a climate-tolerant and climate-adapted mix of tree species.
- The German government's Forest Climate Fund is funding measures to maintain and expand the potential of forests and wood to reduce CO₂ and to help German forests adapt to climate change. This is intended to support achievement of the government's climate targets.
- The government aims to increase the amount of forested land in Germany. New forests primarily made up of native tree species will be planted wherever it is suitable and will be sustainably managed in a near-natural way. Offsetting and compensatory measures following the clearance of forests, for example in connection with infrastructure projects, must include reforestation of an area that is at least equal to the size of the cleared area.
- The German government will work to ensure that greater attention is paid to climate action in the forests funding area of the Joint Task for the Improvement of Agricultural Structures and Coastal Protection. The aim is to fund and maintain more near-natural, productive forests that are adapted to climate change and are primarily made up of native tree species. The question of how forestry associations can be funded under this Joint Task to provide advice on climate action to private forest owners will be examined.
- The German government considers the reinforcement of international cooperation in the areas of conserving, restoring and sustainably managing forests to be a primary instrument for counteracting continued global deforestation and for maintaining the diverse functions of forests in the interest of people and nature, such as climate action and species protection, and as a vital supplier of raw materials over the long term.

In its new edition of the Charter for Wood¹²⁹, the Federal Ministry of Food and Agriculture plans to develop measures to enhance the contribution made by the sustainable use of wood to achieving climate action targets.

Reduction effect

The forests' function as a sink significantly declines between 2014 and 2020, from 57.8 Mt CO₂e to just over 11 Mt CO₂e. The quantity of carbon dioxide bound by forests each year subsequently rises again. This derives from the projected trend in carbon stocks

¹²⁹ Federal Ministry of Food and Agriculture (2017b).

in forests calculated with the WEHAM model. Further information is given in section 3.1.13 of the 2017 Projections Report.

When drawing up the balance of the contribution to climate change mitigation made by forestry it must be borne in mind that the avoided emissions from the use of wood for material and energy that are directly linked to the provision of raw material by the forestry industry are not accounted for in this source category. Instead, they are included in the energy industry, building and housing, transport, and industry and business sectors or source categories as a result of reduced emissions.

4.4 Climate change mitigation activities by the Länder and local authorities

4.4.1 Länder

All 16 German Länder have their own climate action concepts and programmes. They were described in detail in the Sixth National Communication.

Since the finalisation of the Sixth National Communication, other Länder have adopted their own primary legislation on climate change. This is the case in Baden-Württemberg, Berlin, Bremen, Rhineland-Palatinate and Schleswig-Holstein. A draft act was submitted to parliament in Lower Saxony for consultation, and Thuringia has begun preparations for a climate change act. Therefore five Länder now have their own climate change acts, and a further two are in preparation.

Constant communication takes place between the federal government and the Länder in the context of work on the government's two most climate important programmes and strategies, the Climate Action Programme 2020 and the Climate Action Plan 2050. The Länder also provide information about their climate change activities in the annual national climate action report, for example.

Like the federal government, the Länder are constantly developing and refining their climate policy measures and instruments. The most important changes in the Länder during the 2014–2017 reporting period are set out below.

On 15 July 2014, Baden-Württemberg adopted an Integrated Energy and Climate Strategy (IEKK). The Strategy fleshes out the climate targets laid down in Baden-Württemberg's 2013 Climate Change Act on the expansion of renewable energy, energy saving and raising energy efficiency up until 2020 while also considering the security and economic efficiency of energy supply. Implementation of the IEKK is kept under review by means of quantitative and qualitative monitoring. The short monitoring reports for the 2014 and 2015 reporting years were published on the Ministry of the Environment, Climate Protection and the Energy Sector's website. The monitoring report for 2016 is intended to form the basis for updating the Integrated Energy and Climate Strategy in 2019.

To complement the Bavaria 2020 Climate Programme, the Bavarian state government adopted the Climate Policy Programme Bavaria 2050 in 2014.¹³⁰ In line with the European target of reducing greenhouse gas emissions by 80 to 95 % by 2050, Bavaria is aiming to cut annual per capita greenhouse gas emissions to less than two tonnes in that timescale. The measures focus on certain priority areas: boosting energy efficiency and increasing the use of renewable energy in buildings, efficiency measures in industry and the trade,

¹³⁰ Bavarian State Government (2015)

commerce and services sector, and the targeted expansion of natural CO₂ sinks. The programme also includes adaptation measures, particularly in the water industry and forestry. Bavaria presents its climate-related activities on a dedicated website operated by the state government.¹³¹

Berlin's climate targets and the instruments needed to achieve them are laid down in its Energy Transition Act (Energiewendegesetz), which entered into force in April 2016. The aim is that the city should be climate-neutral by 2050, or at least should have reduced its greenhouse gas emissions by 85 % compared with 1990. The Act is complemented by the Berlin Energy and Climate Programme (BEK), which contains the specific strategies and measures for achieving the goal of climate neutrality. The Programme was proposed by the state government and was adopted by the Abgeordnetenhaus (parliament) in June 2017. The Berlin state government also presents information about its climate activities on a separate internet portal.¹³²

The state of Brandenburg presented its first report on the implementation status of its Energy Strategy 2030 in March 2014.¹³³

The state of Bremen's Climate and Energy Act (Klimaschutz- und Energiegesetz) has been in force since March 2015, thereby giving the greenhouse gas emissions reduction targets for 2020 (40 % compared with 1990) the force of law. The aim of the Act is to ensure that the conversion, distribution and use of energy is environmentally sound, resource-efficient, low-risk and cost-effective on a macroeconomic scale. It names the economical use of energy, greater energy efficiency, the increased use of combined heat and power and waste heat and the increased use of renewable energy as suitable action strategies.

Hamburg has continued development of its 2013 Climate Change Master Plan to produce the Hamburg Climate Plan, which was adopted in 2015. Climate change mitigation and adaptation are viewed as an integrated whole within this Plan, which follows the principle of Hamburg becoming a climate smart city. The Plan includes a long-term perspective for 2050 and a plan of action for the 2020–2030 period. The Plan is scheduled to be reviewed and updated every two years, starting in 2016. The plan of action addresses 14 areas of activity and four strategic clusters covering multiple areas of activity.

In March 2017 the government of the state of Hesse adopted an Integrated Climate Action Plan with a total of 140 measures to reduce greenhouse gas emissions and adapt to climate change, 42 of which are high-priority measures that are expected to be put into practice without delay. The aim is to reduce greenhouse gas emissions by 30 % by 2020, by 40 % by 2025 and by at least 90 % by 2050 (compared with 1990 in each case). Additional funding amounting to EUR 140 million was made available for the first implementation phase. The process of drafting the Climate Action Plan was flanked by 27 events for interested members of the public, where individuals and interest groups were able to submit feedback on the proposed measures.¹³⁴

Mecklenburg-Western Pomerania evaluated its Climate Change Strategy in 2015 and subsequently revised 42 measures for its Climate Action Plan.¹³⁵

The state government of Lower Saxony presented a draft Climate Change Act to the state parliament in March 2017. The Act stipulates targets for climate change mitigation and

¹³¹ <http://www.stmuv.bayern.de/themen/klimaschutz/index.htm>, retrieved on 15 June 2017

¹³² <http://www.stadtentwicklung.berlin.de/umwelt/klimaschutz/>, retrieved on 15 June 2017

¹³³ State Government of Brandenburg (2014)

¹³⁴ Hessian Ministry of the Environment, Climate Protection, Agriculture and Consumer Protection (2017)

¹³⁵ State Government of Mecklenburg-Western Pomerania (2016)

adaptation. It is based on a model that was developed in the course of a consultation process with 50 social groups.¹³⁶

To underpin its 2013 Climate Change Act, North Rhine-Westphalia's state parliament adopted the NRW Climate Action Plan in December 2015. The principal elements of the Climate Action Plan are 55 strategies and 220 specific measures, of which 154 measures relate to climate change mitigation and 66 are categorised in 16 fields of activity relating to adaptation to climate change. The measures in the NRW Climate Action Plan contribute to the achievement of targets in 2020, while the strategies have a longer-term focus.

Rhineland-Palatinate's Climate Change Act (Landesgesetz zur Förderung des Klimaschutzes) entered into force in on 23 August 2014.¹³⁷ It established the legal framework for a climate action strategy and also covered appropriate monitoring measures and the enforcement of climate-neutral state administration. The Act specifies reduction targets for emissions of greenhouse gases by 2020 (minus 40 %) and 2050 (climate neutrality, or at least minus 90 %). Monitoring reports are presented every four years, with the first appearing in 2017.

One of the actions taken by the Saarland state government to implement its 2008 Climate Action Strategy was to set up a state support programme, the Municipal Future Energy Programme (Zukunftsenergieprogramm kommunal – ZEP kom) for the period from 2015 to 2023, with funding of EUR 18 million. Another programme, promoting intelligent energy storage systems, has been running since 15 October 2015 and has EUR 1.5 million of funding.

In Saxony-Anhalt the new state government, elected in March 2016, is planning to update its 2020 Climate Action Programme in the light of the outcome of the 2015 Paris Climate Change Conference and the European and national targets.

Saxony presented an implementation report on the plan of measures for the Saxony Energy and Climate Programme in April 2015. According to the report, 90 % of the measures are currently being implemented or have already been completed.

In February 2017 Schleswig-Holstein's state parliament adopted an Energy Transition and Climate Change Act (Energiewende- und Klimaschutzgesetz) with state-wide targets for the energy transition and climate change mitigation, and measures for the state government and local authorities.¹³⁸

On the basis of a mandate from the state parliament, the state government of Schleswig-Holstein presents an energy transition and climate action report with information about targets, measures and monitoring every year in June.

The state government of Thuringia began preparations for a Climate Change Act in 2016.

4.4.2 Local authorities

Thanks to local self-government, local authorities are able to decide on their own initiative to take action on climate change mitigation, independently of federal or state legislation. Some of the Climate Change Acts in the Länder oblige local authorities to participate in certain measures.

¹³⁶ Lower Saxony Ministry of the Environment, Energy and Climate Protection (n.d)

¹³⁷ Rhineland-Palatinate Law Gazette (2014)

¹³⁸ Schleswig-Holstein Law Gazette (2017)

The federal government supports climate activities undertaken by cities and local authorities through the Local Authorities Guideline under the National Climate Initiative funding programme.

In addition, the support and networking services described in the Sixth National Communication, such as the service and competence centre on local authority climate action, are still in place.

4.5 Policies and measures to meet obligations under the Kyoto Protocol (pursuant to Article 2)

4.5.1 Updating the German Sustainable Development Strategy

The German government adopted the German Sustainable Development Strategy – New Version 2016¹³⁹ on 11 January 2017. This is the most comprehensive update to the strategy since it first came into force in 2002. The new Sustainable Development Strategy is heavily influenced by the United Nations 2030 Agenda for Sustainable Development. It specifies goals and measures for implementing the 17 SDGs on three different levels: in Germany, in Germany's bilateral cooperation with partner countries and globally with German support. The strategy describes a sustainability management system with targets and indicators for measuring success, a monitoring system with a biennial monitoring report, responsibilities at federal level and cooperation with Länder and local authorities. The strategy was drawn up with the participation of the public.

4.5.2 Activities in the air and sea transport sector

The Parties to the Kyoto Protocol have made a commitment to continue their efforts to limit or reduce emissions from air and sea transport in the responsible UN organisations, the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). Germany has supported different developments in the two organisations. More details are given in the transport section of the chapter on policies and measures.

4.5.3 Bioenergy

In 2015, bioenergy met 8.5 % of Germany's total gross electricity requirements, 11.9 % of its total heating requirements and 4.6 % of its total fuel requirements.

In its decisions to accelerate the country's energy transition in the summer of 2011, the federal government set the target of having most of Germany's energy supply come from renewables by 2050. Biomass is currently the main renewable energy source in Germany, with the level of use being particularly high in heating. Over the medium term the amount of supply coming from bioenergy will remain constant in absolute terms, so the proportion will decline in relative terms as the share of wind, solar and geothermal energy rises in future. Its role in achieving the targets of the energy transition will mainly evolve qualitatively, with the inclusion of existing voluntary certification systems.

Ensuring sustainable production of the biomass used to produce energy in the Federal Republic of Germany is an important objective for the federal government. Since January 2011, the use of biomass to produce energy in the biofuels and bioliquids sector has been

¹³⁹ German Government (2017b).

subject to European sustainability criteria, particularly requirements to protect land with a high nature value (HNV), land with high carbon levels and peatlands, and to reduce greenhouse gas emissions by at least 35 % compared with fossil fuels. The sustainability criteria also apply to domestic and imported biofuels and bioliquids. The government is working towards the extension of sustainability criteria to include solid and gaseous biofuels in the electricity and heating sector at EU level.

Indirect land use changes occur when biomass to generate energy is produced on land that was previously used to produce biomass for other purposes (such as food or animal feedstuffs); as a result, production of the latter is at least partially displaced to areas with a high carbon content (such as forests or bogs) or a high level of biodiversity. In this way, the use of bioenergy could indirectly cause greenhouse gas emissions and threaten ecologically valuable areas. The European Commission has addressed this problem with an amending directive (Directive (EU) 2015/1513), which among other things provides for a limit on the share of biofuels whose demand for land competes with that of food growing. The Commission also proposes significantly reducing the proportion of such biofuels by 2030.

To make land use comprehensively sustainable, global targets and measures would have to be mainstreamed in the overall perspective and globally implemented, beyond the bioenergy sector. The Sustainable Development Goals (SDGs) offer numerous potential starting points for this. The German government is working to achieve the expansion of sustainable use of bioenergy within the Global Bioenergy Partnership (GBEP). A total of 23 countries and 14 international organisations are partners in GBEP, while many others are observers. The GBEP Indicators are used to analyse the sustainability of using bioenergy based on environmental, economic, and social aspects. Another area of emphasis of the initiative is to expand capacity in developing countries and emerging economies.

4.5.4 Adaptation measures and conflict avoidance in emerging and developing countries

Supporting developing countries in their efforts to adapt to climate change is a very important task for Germany, and is an international responsibility that is entrenched as one of the four pillars of the German Strategy for Adaptation to Climate Change (2008). It strengthens the resilience of poor, vulnerable population groups in developing countries in many ways, for example by ensuring that the provision of basic services is made climate-proof (water/wastewater, precautionary measures against vector-borne diseases, disaster preparedness). Vulnerable areas in sub-Saharan Africa, for instance, are often also areas where conflict takes place, such as the Horn of Africa, the Lake Chad region or the Sahel. Adaptation measures in these areas make poor and vulnerable groups more resilient and have a conflict-reducing effect, either directly or indirectly.

4.5.5 Policies and other measures that expired or were cancelled during the reporting period

During the reporting period no major policies or other climate change mitigation measures expired or, if they did expire, they were transferred to other statutory provisions.

5 Projections and overall impacts of policies and measures to reduce greenhouse gases

The projections presented here are based on the 2017 Projections Report prepared by a consortium of German research institutions from Öko-Institut and the Fraunhofer Institute for Systems and Innovation (ISI) in cooperation with Dr Hans-Joachim Ziesing, commissioned by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety. The report fulfils EU requirements for European emissions reporting.

Some emission projections from other research projects were included in the model calculations. The scenario calculations for the agriculture and LULUCF source categories were done by the Johann Heinrich von Thünen Institute. The key data was specified in early 2016 in coordination with other federal ministries. The Projections Report explores two different scenarios, a “with-measures scenario” (WMS) and a “with-additional-measures scenario” (WAMS). The policies and measures contained in the two scenarios are presented below.

5.1 Projection of total greenhouse gas emissions by sector and type of gas

Figure 25 summarises the main projection results for trends in total greenhouse gas emissions. It shows the raw inventory data for the historical reference years 1990-2014. The projections under the WMS and WAMS from 2020 onwards are shown next to each other to illustrate the additional effects expected from measures that are included in the WAMS but not in the WMS.

For total greenhouse gas emissions (excluding land use, land-use change and forestry and international aviation and maritime transport), the WMS shows a reduction of 175 Mt CO₂e or 18 % for the 2005-2020 period. By 2030, the reduction from 2005 levels is about 257 Mt CO₂e or 26 % and by 2035 it is 323 Mt CO₂e or 33 %. Compared with 1990, this equates to a reduction of 34.7 % by 2020, 41 % by 2030, and over 46 % by 2035. If the sensitivities analysed in the report are taken into consideration, the possible corridor for emissions reduction in 2020 is between 33.7 % (stronger economic growth) and 37.5 % (lower electricity export balance) of the 1990 level.

Under the WAMS there is a reduction in total greenhouse gas emissions (excluding land use, land-use change and forestry and international aviation and maritime transport) of 186 Mt CO₂e or almost 19 % for the 2005-2020 period. By 2030, the reduction compared with 2005 is about 310 Mt CO₂e or over 31 % and by 2035 it is 400 Mt CO₂e or over 40 %. This corresponds to a 35.5 % reduction from 1990 levels by 2020. By 2030 there is a reduction of over 45 % and by 2035 of almost 53 % compared with 1990. If the sensitivities analysed in the report are taken into consideration, the possible corridor for emissions reduction in 2020 is between 34.5 % (stronger economic growth) and 38.4 % (lower electricity export balance) of the 1990 level.

However, it must also be pointed out that the emissions trends described do not include developments in international aviation (and to a lesser extent deep-sea shipping). In particular, the very dynamic trend in international aviation causes the relevant greenhouse gas emissions to increase by more than 4 Mt CO₂e between 2005 and 2020, which equates to a 14 % increase. Since no additional measures are assumed for international transport in the WAMS, this statement applies equally to both scenarios.

Complete tables in accordance with the UNFCCC guidelines showing the results of the greenhouse gas projections are contained in Tables 6a and 6c of the Biennial Report and in sections 5.1.1 and 5.12 below, which discuss energy-related emissions in greater detail.

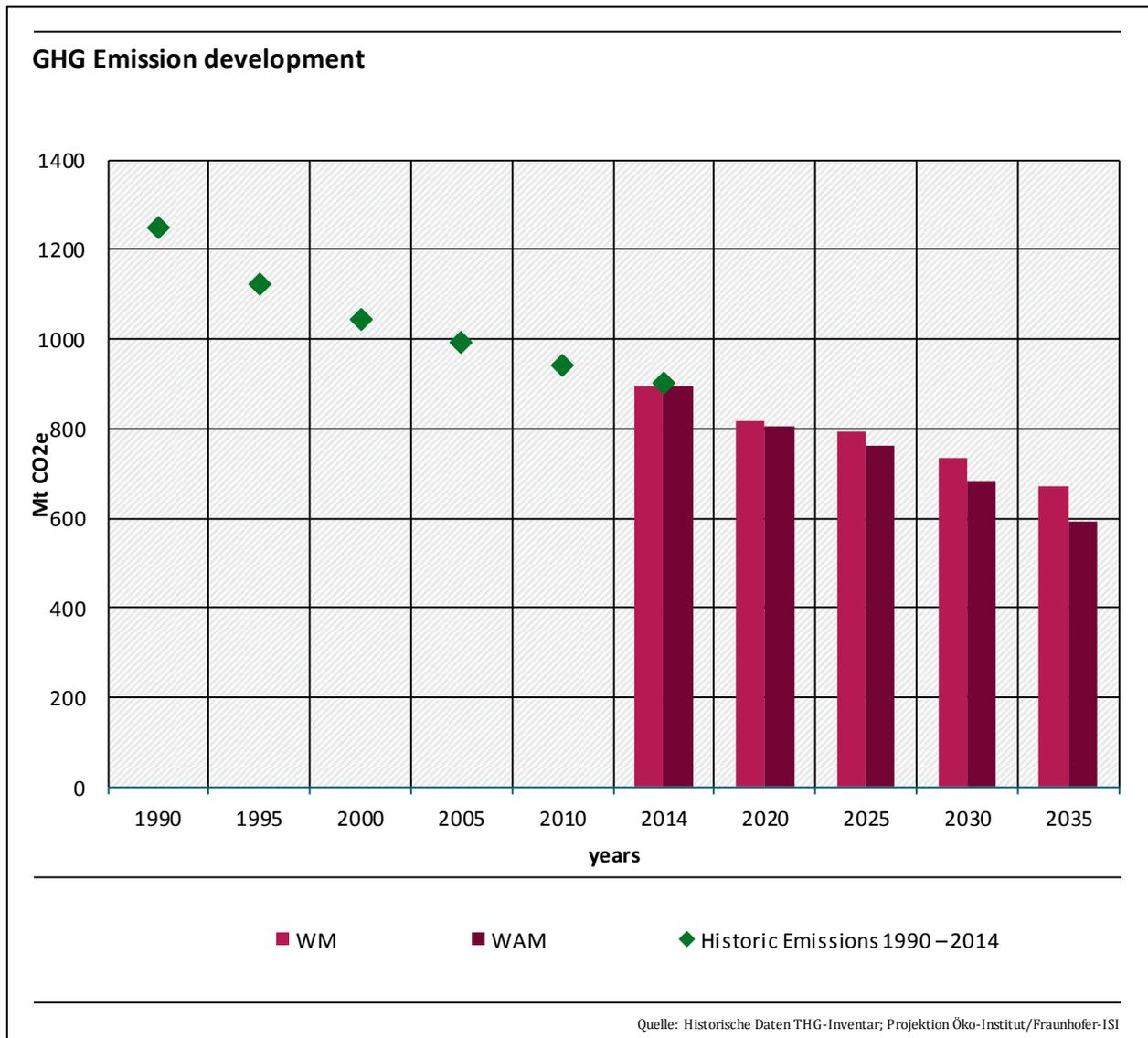


Figure 25: Trends in total greenhouse gases under the WMS and WAMS (1990 2035) ¹⁴⁰

Trends in greenhouse gas emissions under the with-measures and with-additional-measures projection scenarios are aggregated below in two different ways. On the one hand, the contributions made by the different greenhouse gases are depicted and, on the other, the contributions made by the individual source categories. Each of these depictions shows the total greenhouse gas emissions defined in two different ways: with and without emissions from deep-sea shipping and international aviation, and with and without release or sequestration of greenhouse gases in the land use, land use change and forestry sector (LULUCF). The two types of international transport are included in the national Greenhouse Gas Inventories, but only as “memo items” for information. As a rule, emissions from international fuel bunkers (deep-sea shipping and international aviation) and LULUCF do not count towards meeting climate targets in Germany; this report follows this convention.

¹⁴⁰ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

5.1.1 Results of the projection under the with-measures scenario

5.1.1.1 Trends in greenhouse gas emissions by type of gas

Table 7 shows a summary of trends in emissions of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃). This summary does not include greenhouse gas emissions from international fuel bunkers (deep-sea shipping and international aviation) and LULUCF.

By 2014, domestic greenhouse gas emissions were already just less than 28 % down on 1990 and over 9 % down on 2005 in the national balance. Compared with the 1990 reference year, total greenhouse gas emissions fall by just under 35 % (-18 % compared with 2005) from 1,250 to 816 Mt CO₂e up to 2020 and by almost 41 % (-26 % compared with 2005) to 734 Mt CO₂e up to 2030. The German government's goal to reduce greenhouse gas emissions by 40 % by 2020 and 55 % by 2030 compared with 1990 is thus not achieved under the with-measures scenario.

Between 1990 and 2014, annual emissions of carbon dioxide¹⁴¹ were cut by almost 25 %. CO₂ emissions are 44 % lower in 2035 than in 1990. Both historically and in the projection, CO₂ is the gas with the largest share in Germany's total greenhouse gas emissions. In 1990, it accounted for over 84 % and in 2014 for almost 88 % of total greenhouse gas emissions. By 2035, this share falls to about 87 %. CO₂ emissions from the combustion of biomass, which are not included in the total and are therefore reported for information only, soared between 1990 and 2014 and peak around 2020 before declining again.

The greatest reductions in methane emissions have already been achieved in the past: CH₄ was the most important greenhouse gas in 1990, with a share in total emissions of almost 10 %. However, since a 54 % cut in CH₄ emissions had been achieved by 2014, their share in total emissions fell to only slightly more than 6 %. By 2035, CH₄ emissions are a good 62 % down on 1990. However, since the emissions reductions here are disproportionately low, especially from 2020, their percentage rises again slightly to just below 7 % up to 2035.

Nitrous oxide's share in total greenhouse gas emissions was over 5 % in 1990. Here too an almost 41 % cut was achieved by 2014, so that its share in total emissions fell from 5 % to 4 %. However, by contrast with methane, there have been no further reductions in emissions for nitrous oxide. In 2035, N₂O emissions are only slightly lower than in 2014. Their percentage share therefore rises once more to over 5 % in 2035.

In 1990, fluorinated gases accounted for 1.1 % of total greenhouse gas emissions; by 2014, this figure had risen to 1.6 %. By 2020, it increases slightly to 1.7 %, after which it falls to 0.7 % by 2035.

The reductions compared with Kyoto Protocol base year emissions (for which emissions in 1990 were used for CO₂, CH₄ and N₂O and emissions in 1995 for fluorinated gases) are in each case slightly higher than emissions reductions from 1990 levels.

¹⁴¹ CO₂ emissions from incinerating biomass are not included here or in any of the CO₂ emissions discussed in this report.

Greenhouse gas	1990	2005	2010	2014	2020	2025	2030	2035
	Mt CO ₂ e							
Carbon dioxide (CO ₂)	1,052.2	866.0	832.3	792.9	713.2	695.6	646.1	584.1
Methane (CH ₄)	119.2	68.4	58.1	55.5	51.2	49.2	46.7	44.7
Nitrous oxide (N ₂ O)	65.2	43.6	37.0	38.8	37.8	37.7	36.6	35.7
Hydrofluorocarbons (HFCs)	0.1	8.8	9.9	10.8	9.4	7.4	3.6	3.4
Perfluorocarbons (PFCs)	3.1	0.8	0.3	0.2	0.2	0.2	0.2	0.2
Sulphur hexafluoride (SF ₆)	4.3	3.3	3.0	3.4	4.3	2.7	1.2	1.0
Non-specified mix (HFCs/PFCs)	5.7	0.9	0.4	0.2	0.2	0.2	0.2	0.2
Nitrogen trifluoride (NF ₃)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	1,249.8	991.8	941.0	901.8	816.4	793.1	734.5	669.3
Compared with 2005	26.0 %	0.0 %	- 5.1 %	- 9.1 %	- 17.7 %	- 20.0 %	- 25.9 %	- 32.5 %
Compared with 1990	0.0 %	- 20.6 %	- 24.7 %	- 27.8 %	- 34.7 %	- 36.5 %	- 41.2 %	- 46.5 %
Compared with base year ^b	-0.3 %	- 20.9 %	- 24.9 %	- 28.1 %	- 34.9 %	- 36.7 %	- 41.4 %	- 46.6 %
Memo items:								
CO ₂ from biomass combustion	21.8	59.3	108.5	98.5	115.1	108.9	93.5	80.3

Table 8: Trends in total emissions by type of greenhouse gas under the WMS, 1990-2035¹⁴²

Note: ^aNot including CO₂ from biomass combustion.

^b The base year is 1990 for carbon dioxide, methane and nitrous oxide and 1995 for HFCs, PFCs, SF₆ and NF₃. The base year emissions were calculated accordingly.

¹⁴² Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

5.1.1.2 Trends in greenhouse gas emissions by source category

Considering domestic emissions but not including international aviation, maritime transport and LULUCF, greenhouse gas emissions fell by almost 28 % up to 2014 compared with 1990 and by over 9 % compared with 2005. Up to 2020, emissions fall by just under 35 % compared with 1990 (18 % down on 2005) and up to 2035 they fall by over 46 % compared with 1990 (33 % down on 2005) to 669 Mt CO₂e.

Over half the emissions reductions from 2014 to 2035 are achieved by the energy industry. In this sector, emissions fall in absolute terms by 63 Mt CO₂e up to 2020 compared with 2014 and by 125 Mt CO₂e up to 2035. That equates to an 18 % reduction in 2020 compared with 2014 (-34 % compared with 1990) and represents a 36 % reduction in 2035 (48 % lower than in 1990). Whereas the energy industry's share in total emissions (not counting international transport and LULUCF) rose from over 34 % in 1990 to over 38 % in 2014, it falls to about 33 % by 2035.

Energy-related industrial emissions fall by just under 7 Mt CO₂e or 6 % by 2020 (39 % below their 1990 level), and then fall by just under 19 Mt CO₂e or 19 % by 2035 from their 2014 level (48 % down on 1990). Overall, industrial emissions' share rises from over 13 % in 2014 to almost 15 % in 2035.

Greenhouse gas emissions from the trade, commerce and services sector rise by a good 3 Mt CO₂e or 8 % up to 2020 compared with 2014 (-52 % compared with 1990) and then decline by 12 Mt CO₂e or 29 % up to 2035 compared with 2014 (-68 % compared with 1990). The trade, commerce and services sector's share in total emissions remains at about 4 %.

The second largest contribution to the projected reduction in emissions comes from private households: they reduce their emissions by 11 % or 9 Mt CO₂e between 2014 and 2020 (42 % down on 1990) and by 39 % or 33 Mt CO₂e up to 2035 (60 % below 1990 levels). Furthermore, private households' share falls from 9 % in 2014 to less than 8 % in 2035.

Only minor emissions reductions are achieved in the transport sector. They fall by 2 Mt CO₂e or 1 % from 2014 levels (-3 % compared with 1990) in 2020 and by 12 Mt CO₂e or 8 % in 2035 compared with 2014 (-9 % compared with 1990). Nevertheless, the historically rising trend in transport emissions' percentage share continues: whereas in 1990 transport's share in total emissions was still a little over 13 %, it rose to almost 18 % in 2014 and exceeds 22 % by 2035. It must also be noted that, due to the expansion of electric mobility, some of the emissions from the transport sector are shifted to the energy industry, because public electricity generation is accounted for in the latter.

In absolute terms, reductions in fugitive emissions from the energy sector are low but they are high in relative terms: emissions reductions of 3 Mt CO₂e between 2014 and 2020 and of 4 Mt CO₂e up to 2035 equate to decreases from 2014 levels of 28 % in 2020 (80 % down on 1990) and 38 % in 2035 (79 % down on 1990). The relative percentage remains the same at around 1 %.

Emissions from industrial processes were the most important of all the non-energy-related emissions in 1990, accounting for almost 8 % of total emissions; in 2014 their share had fallen to just under 7 %. There is little change in this percentage up to 2035. Nevertheless, emissions from industrial processes fall by almost 1 Mt CO₂e or 1 % between 2014 and 2020 (37 % down on 1990) and by 16 Mt CO₂e or 26 % by 2035 (53 % down on 1990).

Although emissions from agriculture decreased between 1990 and 2014, it has nevertheless become the most important source of greenhouse gases apart from the

energy sector. Furthermore, agriculture is the sector with the lowest projected emissions reduction: just less than 1 Mt CO₂e or 1 % by 2020 compared with 2014 (-17 % compared with 1990) and just over 2 Mt CO₂e or 4 % by 2035 compared with 2014 (-19 % compared with 1990). This also means that agriculture's share in total emissions rose from over 6 % in 1990 to 7 % in 2014 and reaches almost 10 % in 2035.

Waste management is the sector with the historically highest emissions reductions in relative terms, experiencing an almost 70 % decline in emissions between 1990 and 2014. Nevertheless, emissions from the waste management sector are reduced by a further 3 Mt CO₂e or 25 % between 2014 and 2020 and by almost 7 Mt CO₂e or 57 % up to 2035. This means that waste management continues to be the sector with the greatest emissions reductions in relative terms – 77 % in 2020 and 87 % in 2035 (compared with 1990 levels).

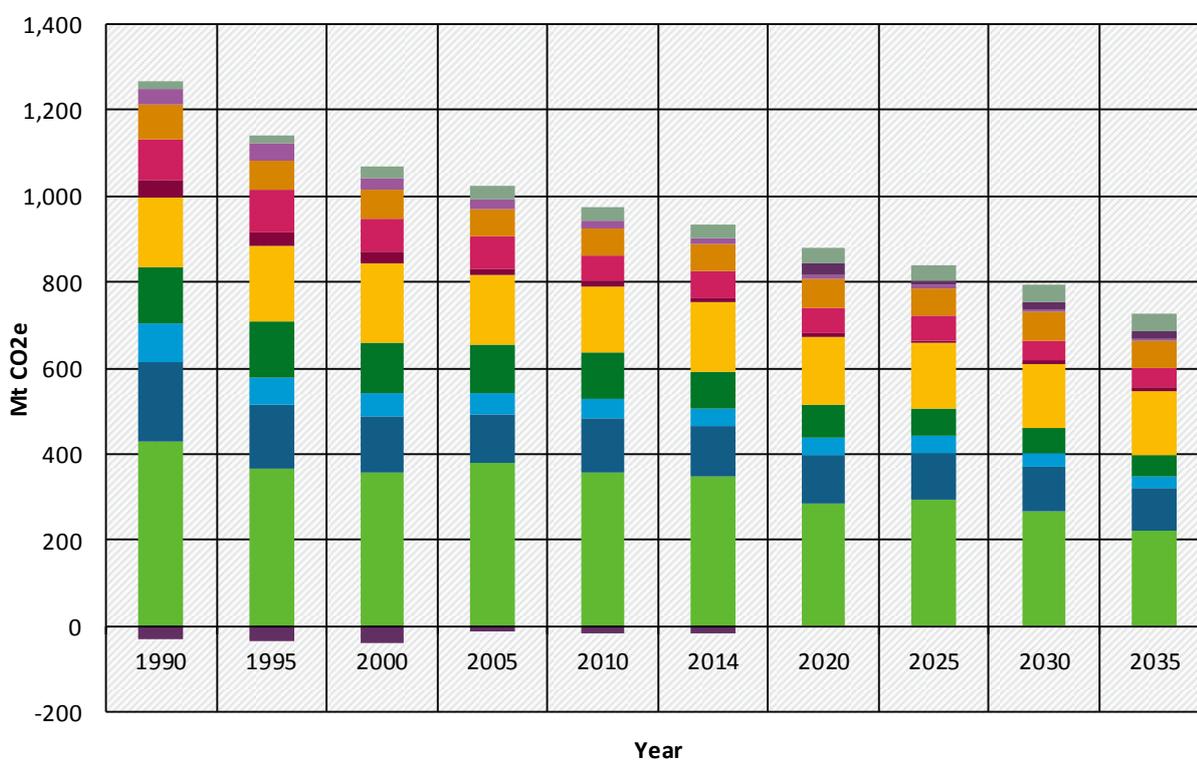
The rise in agricultural emissions and only slight decrease in emissions from the waste management sector explain the below-average decrease in methane and nitrous oxide emissions described in the section on projection results for agriculture.

Whereas in the past the LULUCF sector was an overall sink, in the projection it is a source of emissions.

Emissions from the proportion of international aviation and maritime transport that is attributable to Germany rose by over 68 % between 1990 and 2014. These emissions rise by a further 3 Mt CO₂ or 10 % up to 2020 and by 7 Mt CO₂e or 25 % up to 2035 compared with 2014. This means that emissions from international aviation and maritime transport are 85 % higher in 2020 than in 1990 and in 2035 they are actually more than twice as high as in 1990.

Taking international maritime transport and aviation into account, total emissions from transport in 2014 were just under 26 % and just over 9 % lower than in 1990 and 2005 respectively and fall by 29 % between 1990 and 2020 (-13 % compared with 2005) and by 44 % up to 2035 (-32 % compared with 2005).

Greenhouse gas emissions under the WMS according to the inventory structure



- Energy industry
- Industry
- Trade, commerce and services
- Households
- Transport
- Fugitive emissions
- Industrial processes
- Agriculture

Source: Historical data from the GHG inventory; projection by Öko-Institut/Fraunhofer-ISI

Figure 26: Trends in total greenhouse gas emissions by source category under the WMS (1990-2035) (not including international fuel bunkers)¹⁴³

Source category	1990	2005	2010	2014	2020	2025	2030	2035
	Mt CO ₂ e							
Energy industry	427.4	378.8	356.2	346.3	283.0	294.9	267.9	221.4
Industry	186.7	115.2	125.2	119.7	113.1	108.1	101.3	97.5
Trade, commerce and services	88.4	47.9	47.6	39.5	42.5	37.5	32.7	27.9
Households	130.8	111.9	106.9	85.2	75.7	65.0	57.8	52.5
Transport	164.4	161.4	154.2	161.1	159.1	152.7	150.0	148.9
Fugitive emissions	38.0	16.4	11.3	10.5	7.6	7.2	6.8	6.5

¹⁴³ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

Source category	1990	2005	2010	2014	2020	2025	2030	2035
	Mt CO ₂ e							
from fuels								
Industrial processes	96.4	75.3	62.0	61.0	60.3	54.4	47.0	45.1
Agriculture	79.8	63.6	63.0	66.9	66.3	66.3	65.1	64.5
Waste management	38.0	21.2	14.6	11.6	8.6	7.0	5.9	5.0
Total	1,249.8	991.8	941.0	901.8	816.4	793.1	734.5	669.3
Compared with 2005	26.0 %	0.0 %	-5.1 %	-9.1 %	-17.7 %	-20.0 %	-25.9 %	-32.5 %
Compared with 1990	0.0 %	-20.6 %	-24.7 %	-27.8 %	-34.7 %	-36.5 %	-41.2 %	-46.5 %
Compared with base year ^a	-0.3 %	-20.9 %	-24.9 %	-28.1 %	-34.9 %	-36.7 %	-41.4 %	-46.6 %
Memo items:								
LULUCF	-31.3	-12.1	-16.3	-15.0	29.1	11.2	19.2	18.7
International aviation and maritime transport	18.6	30.1	32.5	31.3	34.4	36.8	38.8	39.2
Total, incl. memo items	1,237.1	1,009.9	957.2	918.1	879.9	841.0	792.5	727.2
Compared with 2005	22.5 %	0.0 %	-5.2 %	-9.1 %	-12.9 %	-16.7 %	-21.5 %	-28.0 %
Compared with 1990	0.0 %	-18.4 %	-22.6 %	-25.8 %	-28.9 %	-32.0 %	-35.9 %	-41.2 %
Compared with base year ^a	-0.3 %	-18.6 %	-22.9 %	-26.0 %	-29.1 %	-32.2 %	-36.1 %	-41.4 %

Table 9: Trends in total greenhouse gas emissions by source category under the WMS, 1990-2035¹⁴⁴

Note: ^aThe base year is 1990 for carbon dioxide, methane and nitrous oxide and 1995 for HFCs, PFCs, SF₆

¹⁴⁴ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

and NF₃. The base year emissions were calculated accordingly.

5.1.2 Results of the projection under the with-additional-measures scenario

5.1.2.1 Trends in greenhouse gas emissions by type of gas

Table 9 shows a summary of trends in emissions of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃). This summary does not include greenhouse gas emissions from international fuel bunkers (deep-sea shipping and international aviation) and LULUCF.

By 2014, domestic greenhouse gas emissions were already just less than 28 % down on 1990 and almost 9 % down on 2005 in the national balance. By comparison with the 1990 reference year, total greenhouse gas emissions fall by almost 36 % (19 % compared with 2005) to almost 806 Mt CO₂e by 2020 and by 45 % (31 % compared with 2005) to 682 Mt CO₂e by 2030. The German government's goal to reduce greenhouse gas emissions by 40 % by 2020 and 55 % by 2030 compared with 1990 is thus not achieved under the with-additional-measures scenario either.

It is evident that the measures analysed in the with-additional-measures scenario do not begin to have an impact until after 2025. In 2020, the additional emissions reduction brought about by the WAMS scenario compared with the WMS totalled only 11 Mt CO₂e; that figure rises to 33 Mt CO₂e in 2025 and to 53 Mt CO₂e in 2030.

Between 1990 and 2014, annual emissions of carbon dioxide¹⁴⁵ were cut by almost 25 %. CO₂ emissions in 2035 are almost 52 % lower than in 1990. Both historically and in the projection, CO₂ is the gas with the largest share in Germany's total greenhouse gas emissions. In 1990, it accounted for 84 % and in 2014 for almost 88 % of total greenhouse gas emissions. By 2035, this share falls to about 86 %. CO₂ emissions from the combustion of biomass, which are not included in the total and are therefore reported for information only, soared between 1990 and 2014 and peak around 2020 before declining again.

The greatest reductions in methane emissions have already been achieved in the past: CH₄ was the most important greenhouse gas in 1990, with a share in total emissions of almost 10 %. However, since a 54 % cut in CH₄ emissions had been achieved by 2014, their share in total emissions fell to only slightly more than 6 %. By 2035, CH₄ emissions are at least 63 % down on 1990. However, since the emissions reductions here are disproportionately low, especially from 2020, their percentage rises again slightly to over 7 % by 2035.

Nitrous oxide's share in total greenhouse gas emissions was over 5 % in 1990. Here too an almost 40 % cut was achieved by 2014, so that its share in total emissions fell from 5 % to 4 %. The decrease in N₂O emissions up to 2035 is disproportionately low. This explains why nitrous oxide emissions also account for almost 6 % in 2035 under the WAMS.

In 1990, fluorinated gases accounted for 1.1 % of total greenhouse gas emissions; by 2014, this figure had risen to 1.6 %. By 2020, it increases slightly to 1.7 %, after which it falls to 0.8 % by 2035.

¹⁴⁵ CO₂ emissions from combustion of biomass are not included here or in any of the CO₂ emissions discussed in this report.

Greenhouse gas	1990	2005	2010	2014	2020	2025	2030	2035
	Mt CO ₂ e							
Carbon dioxide (CO ₂)	1,052.2	866.0	832.3	792.9	704.8	666.9	595.9	509.7
Methane (CH ₄)	119.2	68.4	58.1	55.5	51.1	49.0	46.5	44.4
Nitrous oxide (N ₂ O)	65.2	43.6	37.0	38.8	35.8	35.8	34.5	33.4
Hydrofluorocarbons (HFCs)	0.1	8.8	9.9	10.8	9.1	5.4	3.6	3.4
Perfluorocarbons (PFCs)	3.1	0.8	0.3	0.2	0.2	0.2	0.2	0.2
Sulphur hexafluoride (SF ₆)	4.3	3.3	3.0	3.4	4.3	2.7	1.2	1.0
Non-specified mix (HFCs/PFCs)	5.7	0.9	0.4	0.2	0.2	0.2	0.2	0.2
Nitrogen trifluoride (NF ₃)	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0
Total	1,249.8	991.8	941.0	901.8	805.6	760.2	682.0	592.3
Compared with 2005	26.0 %	0.0 %	- 5.1 %	- 9.1 %	- 18.8 %	- 23.4 %	- 31.2 %	- 40.3 %
Compared with 1990	0.0 %	- 20.6 %	- 24.7 %	- 27.8 %	- 35.5 %	- 39.2 %	- 45.4 %	- 52.6 %
Compared with base year	-0.3 %	- 20.9 %	- 24.9 %	- 28.1 %	- 35.7 %	- 39.4 %	- 45.6 %	- 52.8 %
Memo items:								
CO ₂ from biomass combustion	21.8	59.3	108.5	98.5	112.5	105.7	89.7	74.2

Table 10: Trends in total emissions by type of greenhouse gas under the WAMS, 2005-2035¹⁴⁶

Note: ^aThe base year is 1990 for carbon dioxide, methane and nitrous oxide and 1995 for HFCs, PFCs, SF₆ and NF₃. The base year emissions were calculated accordingly.

5.1.2.2 Trends in greenhouse gas emissions by source category

Considering domestic emissions but not including international aviation and maritime transport and LULUCF, greenhouse gas emissions fell by almost 28 % up to 2024

¹⁴⁶ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

compared with 1990 and by over 9 % compared with 2005. By 2020, emissions fall to just under 36 % compared with 1990 (19 % down on 2005) and by 2035 they fall by almost 53 % compared with 1990 (40 % down on 2005) to 592 Mt CO₂e.

Over half the emissions reductions from 2014 to 2035 are achieved by the energy industry. In this sector, emissions fall in absolute terms by 69 Mt CO₂e between 2014 and 2020 and by 169 Mt CO₂e up to 2035. That equates to an 18 % reduction in 2020 compared with 2014 (-34 % compared with 1990) and represents a 36 % reduction in 2035 (48 % lower than in 1990). The additional emissions reduction by the energy industry under the WAMS as compared to the WMS totals almost 45 Mt CO₂e in 2035. Whereas the energy industry's share in total emissions (not counting international transport and LULUCF) rose from just over 34 % in 1990 to almost 38 % in 2014, it falls to under 30 % by 2035.

Energy-related industrial emissions fall by almost 9 Mt CO₂e up to 2020 or 7 % from their 2014 level (41 % down on 1990) and then fall by just under 28 Mt CO₂e up to 2035 or 23 % from their 2014 level (51 % down on 1990). The additional reduction in energy-related emissions from industry under the WAMS as compared to the WMS is over 5 Mt CO₂e in 2035. Overall, industrial emissions' share rises from 13 % in 2014 to almost 16 % in 2035.

Greenhouse gas emissions from the trade, commerce and services sector – as under the WMS – rise by more than 3 Mt CO₂e or 7 % up to 2020 compared with 2014 (-52 % compared with 1990) and then decline by 13 Mt CO₂e or 33 % up to 2035 compared with 2014 (-70 % compared with 1990). The additional emissions reduction by the trade, commerce and services sector under the WAMS as compared to the WMS totals almost 1 Mt CO₂e in 2035. The trade, commerce and services sector's share in total emissions – as under the WMS – remains the same at about 4 %.

The second largest contribution to the projected reduction in emissions under the WAMS also comes from private households: they reduce their emissions by 11 % or 9 Mt CO₂e between 2014 and 2020 (42 % down on 1990) and by 41 % or 35 Mt CO₂e up to 2035 (61 % down on 1990). The additional emissions reduction by households under the WAMS as compared to the WMS totals almost 2 Mt CO₂e in 2035. The trade, commerce and services sector's share in total emissions remains the same at about 9 %.

After the energy industry and private households, the domestic transport sector achieves the greatest long-term emissions reductions in absolute terms. In 2020 the reduction is only 3 Mt CO₂e or 2 % compared with 2014 (-4 % compared with 1990). By 2035, the emissions reduction from domestic transport increases to 33 Mt CO₂e, which is 21 % up on 2014 (down 22 % on 1990). The additional emissions reduction by transport under the WAMS as compared to the WMS totals almost 21 Mt CO₂e in 2035. Nevertheless, the historically rising trend in transport emissions' percentage share also continues under the WAMS: whereas in 1990 transport's share in total emissions was still a little over 13 %, it rose to almost 18 % in 2014 and exceeds 22 % in 2035 under the WAMS.

In absolute terms, reductions in fugitive emissions from the energy sector are low, but they are high in relative terms. The additional emissions reductions under the WAMS are minimal. The relative percentage also remains the same at around 1 %.

Emissions from industrial processes were the most important of all the non-energy-related emissions in 1990, accounting for almost 8 % of total emissions; there is little change in this percentage under the WAMS. Emissions from industrial processes up to 2035 are only minimally lower under the WAMS than under the WMS. By 2035, emission levels are 54 % lower than in 1990.

Although emissions from agriculture decreased between 1990 and 2014, it has nevertheless become an important source of greenhouse gases. Furthermore, agriculture is the source category where only very low emissions reductions are projected: just less than 3 Mt CO₂e or 4 % between 2014 and 2020 (-20 % compared with 1990) and over 4 Mt CO₂e or almost 7 % up to 2035 (-22 % compared with 1990). This also means that agriculture's share in total emissions rises from 7 % in 2014 to almost 11 %. The additional emissions reduction achieved by agriculture under the WAMS as compared to the WMS totals about 3 Mt CO₂e in 2035.

Waste management is the sector with the highest historical emissions reductions in relative terms (-70 % in 2014 compared with 1990). Emissions under the WAMS decrease further up to 2035. The additional emissions reduction under the WAMS as compared to the WMS totals 0.4 Mt CO₂e in 2035. Waste management thus continues to be the sector with the greatest emissions reductions in relative terms – 88 % in 2035 (compared with 1990 levels).

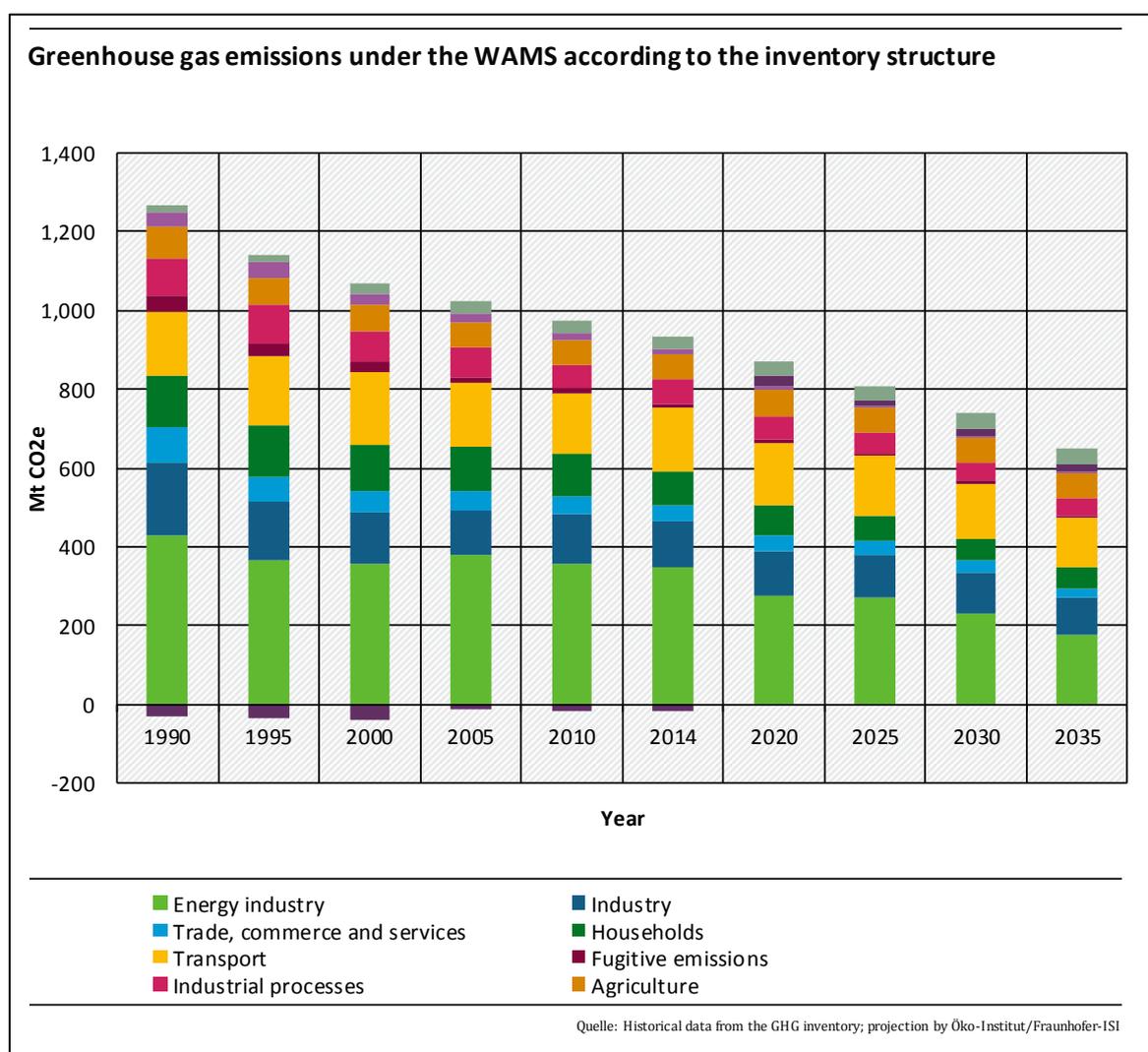


Figure 27: Trends in total greenhouse gases by source category under the WAMS (1990-2035)¹⁴⁷

¹⁴⁷ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

Source category	1990	2005	2010	2014	2020	2025	2030	2035
	Mt CO ₂ e							
Energy industry	427.4	378.8	356.2	346.3	277.4	272.4	232.6	176.9
Industry	186.7	115.2	125.2	119.7	110.8	106.3	100.2	92.1
Trade, commerce and services	88.4	47.9	47.6	39.5	42.5	37.0	31.7	26.6
Households	130.8	111.9	106.9	85.2	76.0	64.2	56.3	50.7
Transport	164.4	161.4	154.2	161.1	158.4	149.7	139.0	127.7
Fugitive emissions from fuels	38.0	16.4	11.3	10.5	7.6	7.2	6.8	6.4
Industrial processes	96.4	75.3	62.0	61.0	60.1	52.4	46.9	44.8
Agriculture	79.8	63.6	63.0	66.9	64.2	64.3	63.1	62.5
Waste management	38.0	21.2	14.6	11.6	8.5	6.6	5.5	4.6
Total	1,249.8	991.8	941.0	901.8	805.6	760.2	682.0	592.3
Compared with 2005	26.0 %	0.0 %	-5.1 %	-9.1 %	-18.8 %	-23.4 %	-31.2 %	-40.3 %
Compared with 1990	0.0 %	-20.6 %	-24.7 %	-27.8 %	-35.5 %	-39.2 %	-45.4 %	-52.6 %
Compared with base year ^a	-0.3 %	-20.9 %	-24.9 %	-28.1 %	-35.7 %	-39.4 %	-45.6 %	-52.8 %
Memo items:								
LULUCF	-31.3	-12.1	-16.3	-15.0	29.1	11.2	19.2	18.7
International aviation and maritime transport	18.6	30.1	32.5	31.3	34.4	36.8	38.8	39.2
Total, incl. memo items	1,237.1	1,009.9	957.2	918.1	869.1	808.1	740.0	650.2
Compared with 2005	22.5 %	0.0 %	-5.2 %	-9.1 %	-13.9 %	-20.0 %	-26.7 %	-35.6 %

Source category	1990	2005	2010	2014	2020	2025	2030	2035
					%	%	%	%
Compared with 1990	0.0 %	- 18.4 %	- 22.6 %	- 25.8 %	- 29.7 %	- 34.7 %	- 40.2 %	- 47.4 %
Compared with base year ^a	-0.3 %	- 18.6 %	- 22.9 %	- 26.0 %	- 30.0 %	- 34.9 %	- 40.4 %	- 47.6 %

Table 11: Trends in total greenhouse gases by source category under the WAMS, 1990-2035¹⁴⁸

Note: ^aThe base year is 1990 for carbon dioxide, methane and nitrous oxide and 1995 for HFCs, PFCs, SF₆ and NF₃. The base year emissions were calculated accordingly.

¹⁴⁸ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

5.2 Estimate of the aggregate impact of policies and measures

Table 11 shows the reduction effects of the quantified instruments in the with-measures scenario. It should be noted that some of the instruments in the demand sectors do not lead to a reduction in direct emissions – at least not exclusively – but also reduce electricity consumption. The overall impact of this reduction is quantified in the energy industry sector (electricity savings resulting from measures in other sectors). No reduction effect for the waste management industry was shown for 2025 under the WMS.

Direct emissions reductions by all measures under the WMS in each sector ¹⁴⁹	2020	2025	2030	2035
	Mt CO ₂ e			
Energy industry	17.0	2.0	9.0	10.0
Industry	6.1	10.1	12.2	12.6
Trade, commerce and services	0.0	0.0	0.0	0.0
Households	4.7	9.3	15.7	16.4
Transport	0.8	0.8	0.6	0.5
Fugitive emissions from fuels	0.0	0.0	0.0	0.0
Industrial processes	4.7	9.3	15.7	16.4
Agriculture	0.0	0.6	0.6	0.7
Waste management	0.2	0.1	-0.2	-0.2
Total	33.5	32.2	53.6	56.4
LULUCF	1.3	2.5	3.7	4.9
Total with LULUCF	34.8	34.7	57.3	61.3

Table 12: Direct emissions reduction achieved through climate policy instruments under the WMS, summarised by sector¹⁵⁰

Table 12 shows the reduction effects of the additional quantified instruments under the with-additional-measures scenario as compared to the WMS.

Direct emissions reductions resulting from all additional measures under the WAMS in each sector ¹⁵¹	2020	2025	2030	2035
	Mt CO ₂ e			
Energy industry	9.0	23.0	32.0	41.0
Industry	2.5	4.0	5.4	6.9

¹⁴⁹ Sectors correspond to the source categories in the Greenhouse Gas Inventory.

¹⁵⁰ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

¹⁵¹ Sectors correspond to the source categories in the Greenhouse Gas Inventory.

Trade, commerce and services	0.0	0.0	0.0	0.0
Households	0.2	2.0	0.0	0.0
Transport	0.6	3.3	11.0	21.1
Fugitive emissions from fuels	0.0	0.0	0.0	0.0
Industrial processes	0.2	2.0	0.0	0.0
Agriculture	2.6	2.7	3.0	2.9
Waste management	0.2	0.6	0.8	0.5
Total	15.3	37.6	52.2	69.5
LULUCF	0.0	0.0	0.0	0.0
Total with LULUCF	15.3	37.6	52.2	69.5

Table 13: Direct additional emissions reduction achieved through climate policy instruments under the WAMS, summarised by sector¹⁵²

Table 13 contains the complete reduction effects under the WAMS resulting from all measures under the WMS and the WAMS taken together.

Direct emissions reductions resulting from all measures under the WAMS for each sector ¹⁵³	2020	2025	2030	2035
	Mt CO ₂ e			
Energy industry	26.0	25.0	41.0	51.0
Industry	8.6	14.1	17.6	19.6
Trade, commerce and services	0.0	0.0	0.0	0.0
Households	4.9	11.3	15.7	16.4
Transport	1.4	4.1	11.6	21.6
Fugitive emissions from fuels	0.0	0.0	0.0	0.0
Industrial processes	4.9	11.3	15.7	16.4
Agriculture	2.6	3.3	3.6	3.6
Waste management	0.4	0.7	0.6	0.4
Total	48.8	69.8	105.8	125.4
LULUCF	1.3	2.5	3.7	4.9
Total with LULUCF	50.1	72.3	109.5	130.3

Table 14: Direct emissions reduction achieved through climate policy instruments under the WAMS,

¹⁵² Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

¹⁵³ Sectors correspond to the source categories in the Greenhouse Gas Inventory.

summarised by sector¹⁵⁴

5.3 Methodological approach

Projections of German greenhouse gas emissions through 2035 are prepared on the basis of assumptions for:

- Population trends
- Economic and structural trends
- Energy price trends
- Policies and measures

Two scenarios are explored with regard to policies and measures:

- The with-measures scenario (WMS) takes into account all measures in place by 31 July 2016. It also contains measures from the Climate Action Programme 2020 which have already been implemented. The trend resulting from those measures is compared against a (hypothetical) situation that would have occurred had these measures not been put in place or had existing policies and measures not been amended. The measures taken into consideration are those that were in force before the start date of the measures covered by the WMS.¹⁵⁵
- The with-additional-measures scenario (WAMS) primarily reflects the policy measures that are set out in the interministerial Climate Action Programme 2020 and the National Action Plan on Energy Efficiency (NAPE) but have not yet been implemented.
- The Action Programme responds to the current trend for greenhouse gas emissions, which looks likely to miss the national target of a 40 % reduction by 2020 compared with 1990 levels by five to eight percentage points, as shown in the 2013 Projections Report. In addition to individual measures at the sectoral level, it contains an unspecified increase in emissions trading, which is not included here due to the European Commission's uniform requirements for the prices of emission allowances under the WMS and WAMS. The purpose of NAPE is to increase energy efficiency on the demand side.
- Both the Climate Action Programme and NAPE distinguish between centralised policy measures, whose effect on reducing greenhouse gas emissions or energy consumption has been quantified, additional flanking measures, and measures that will not be defined and operationalised until that can be done as part of more extensive working processes in the future. The with-additional-measures scenario also makes that distinction in that it classifies most of the centralised policy measures as instruments to be quantified. Although the flanking measures are important components of the set of instruments, they are not individually quantified using other instruments, because they often have little direct effect and rarely overlap with other instruments.

¹⁵⁴ Projections report 2017; German version available online at: http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/envwqc4_g/170426_PB_2017_-_final.pdf; English version available online in due course at: <http://acm.eionet.europa.eu/>.

¹⁵⁵ Exactly how the different measures are classified differs from sector to sector. The start date of the measures covered by the WMS is explicitly recorded in the overview tables. All the policies and measures in place before the start date named are thus classified as part of the without measures scenario (WOM). The WOM situation was ascertained on a sector-specific basis, but the individual sector analyses were not combined to produce an overall scenario.

The process of analysing and evaluating the different measures, calculating greenhouse gas emissions by source category and ascertaining the background information and indicators needed for the projections is based on different methodological approaches and sets of models for the different sectors which permit an adequate analysis based on the data and information available for those sectors.

For energy-related greenhouse gas emissions from combustion processes, the analyses are based on a complex system of different models (Figure 128):¹⁵⁶

- a) Electricity generation from fossil fuels and from renewable energy sources is analysed using Öko-Institut models (ELIAS/PowerFlex). They also model generation of heat in CHP units.
- b) Energy consumption figures are integrated and primary energy consumption and the energy used in other energy conversion sectors are determined using Öko-Institut's EnUSEM integration model.
- c) For the transport sector, the demand for transport used in the WMS is taken from the transport interdependence forecast for 2030 and updated for the period up to 2035. The Öko-Institut's TEMPS model is used for modelling.
- d) For the buildings sector (residential and non-residential buildings), the INVERT/EE-Lab model of the Fraunhofer Institute for Systems and Innovation Research (ISI) was used.
- e) Analyses for the remaining fuel and electricity demand in the private household sector were carried out using the FORECAST model at Fraunhofer ISI.
- f) The analyses for the electricity and fuel requirement of industry and the commerce, trade and services sector were carried out using the FORECAST model at Fraunhofer ISI, which is based on individual sector models.

¹⁵⁶The model components are described in detail for the individual sectors in Chapter 3.1 of the 2017 Projections Report: <http://acm.eionet.europa.eu/>. The EEA data server also includes a fact sheet on the models that are used: http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/; English version will be available in due course at <http://acm.eionet.europa.eu/>.

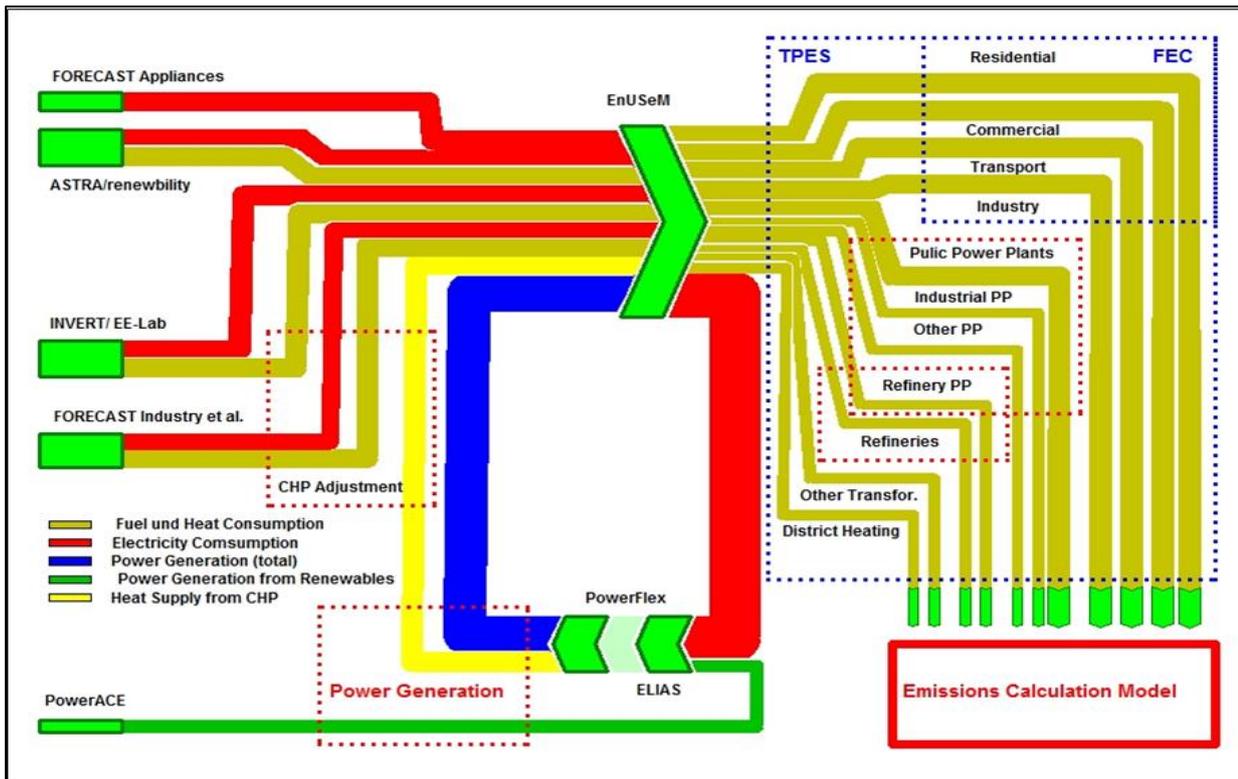


Figure 28: Overview of models used to analyse energy-related greenhouse gas emissions¹⁵⁷

Greenhouse gas emissions from combustion processes were ascertained using Öko-Institut's emissions model, which evaluates emissions aspects of the energy demand projections aggregated in EnUSEM for the various end-use and conversion sectors within the national greenhouse gas emissions system.

For fugitive emissions in the energy sector, Öko-Institut's emissions model carries out source category-specific modelling based on energy demand and supply volumes and the methods used in the National Greenhouse Gas Inventory.

Three different approaches are used for emissions from industrial processes:

- For process-related emissions connected with the energy sector,¹⁵⁸ emissions are ascertained on the basis of the energy demand and supply volumes in Öko-Institut's emissions model, using the methods employed in the National Greenhouse Gas Inventory.
- For process-related emissions that are not connected with the energy sector, emissions are ascertained on the basis of production estimates in Öko-Institut's emissions model, based on the methods employed in the National Greenhouse Gas Inventory.
- For HFC, PFC, SF₆ and NF₃ emissions, existing projections were updated and adjusted.

Projections of greenhouse gas emissions by agriculture and by land use, land use change and forestry (LULUCF) were prepared by the Johann Heinrich von Thünen-Institute.

¹⁵⁷ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

¹⁵⁸ These are primarily methane emissions from coal mining and methane emissions from the extraction and distribution of natural gas.

Öko-Institut's multi-phase waste model used to prepare the National Greenhouse Gas Inventories was expanded to create the projection for greenhouse gas emissions from the waste management sector.

To analyse energy-related greenhouse gas emissions, a principal component analysis was also used, with which a singular value decomposition analysis can then be performed to describe emissions trends on the basis of trends in population growth, economic growth, the energy productivity of the economy as a whole, the share of fossil fuels in the total primary energy supply and the greenhouse gas intensity of the fossil energy sources used.

In addition to generating the WMS and WAMS, this set of models was used in the 2017 Projections Report to perform sensitivity analyses for both scenarios assuming faster population growth, more economic development and lower energy prices, along with lower energy prices combined with a lower CO₂ price pathway.¹⁵⁹

Most of the calculations for the scenarios contained in this report are based on the National Greenhouse Gas Inventory. The most recent Greenhouse Gas Inventory available at the time this scenario was calculated is from the 2016 reporting year and was prepared in accordance with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories using global warming potentials from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. The primary data sources used to prepare this report are the historical data in the Greenhouse Gas Inventory and data consistent with the inventory, which was downloaded from the Central System for Emissions (ZSE) at UBA. The Greenhouse Gas Inventory is not completely compatible with the energy balances for the Federal Republic of Germany (due to different sector definitions and fuel aggregations, for example). Therefore, there are differences between the inventory and the energy balance in some cases. The Greenhouse Gas Inventory contains only activity data on fuel-based energy sources. The energy balances are the primary source of data for non-fuel-based energy sources.

The focus of the evaluation of measures is the reduction in domestic emissions according to the classification used in the inventories. Interactions between measures and the EU emissions trading scheme therefore cannot be taken into account.

The historical greenhouse gas emissions in the report are based on the version of the National Greenhouse Gas Inventory sent to the UNFCCC on 7 November 2016. The new Greenhouse Gas Inventory was sent to the European Commission on 15 January 2017. That update of the National Greenhouse Gas Inventory could not be included in this report.

The Projections Report, which contains a more detailed description of the methodology used, and a fact sheet for the models used can be found on the EEA data server.¹⁶⁰

5.3.1 Summary of key variables and assumptions

A number of important frameworks play a decisive role in developing the energy demand and emissions scenarios. This applies both to key demographic and economic data and to trends in energy prices. To produce the projections, the recommendations under the EU Commission's Monitoring Mechanism Regulation (MMR) were followed for the trends in resident population, gross domestic product, crude oil prices and the price of EU emission

¹⁵⁹ See Federal Ministry for the Environment, Nature Conservation, Construction and Reactor Safety (2017), Chapter 3.5. (<http://acm.eionet.europa.eu/>); English version available in due course online on <http://acm.eionet.europa.eu/>

¹⁶⁰ http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/; English version available in due course at <http://acm.eionet.europa.eu/>

allowances. Furthermore, data published up to 31 July 2016 were used for both the with-measures scenario and with-additional-measures scenario. To ensure consistency between the two modelled scenarios, it was not possible to include data published after this date. Table 14 gives an overview of the most important key data used in the scenarios.

The scenarios are based on demographic trends in which the German resident population reaches its highest level around 2002, then falls up to 2011, rises minimally between 2012 and 2014 and then decreases slightly but steadily in the years to follow, with just under 79 million inhabitants expected for 2035. The number of private households increases slightly in the same period as a result of the trend towards smaller households.

Relatively steady growth is assumed for economic development up to 2035. Gross value added in the manufacturing sector experiences strong growth in the same period, rising from €₍₂₀₁₀₎473 billion in 2015 to €₍₂₀₁₀₎542 billion. A slight increase of about 1.1 million in the number of employees in the private and public services sectors is expected between 2015 and 2030. After 2030, there is a slight fall in the number of employees in these sectors. The price for crude oil in 2035 is significantly higher than in 2015.

	2015	2020	2025	2030	2035
Demographic trends					
Resident population (million)	81.4	80.6	80.3	79.7	78.8
Private households (million)	40.1	40.9	41.1	41.3	41.5
Economic development					
Gross domestic product (€ ₂₀₁₀ billion) ¹⁶¹	2,783	2,968	3,120	3,246	3,362
Gross value added in the manufacturing sector (€ ₂₀₁₀ billion)	473	498	519	533	542
Employees in the service sector (million)	28.8	29.3	29.6	29.9	29.8
Primary energy prices (€₂₀₁₃/GJ_{NCV})					
Crude oil	8.2	12.8	14.5	16.0	16.6
Coal 2.4	2.4	2.4	2.9	3.5	3.7
Natural gas	6.1	7.5	8.1	8.8	9.4
EU carbon allowance prices (€/EUA)					
WMS and WAMS	7.5	15.0	22.5	33.5	42.0

Table 15: Selected key demographic and economic data, 2015-2035¹⁶²

¹⁶¹ The 2014 National Accounts Revision implements the regulations of the European System of National and Regional Accounts (ESA 2010) and increases GDP for 2013 by approximately EUR 80 billion. To ensure comparability with other studies, the figures in the table representing the Federal Statistical Office's trajectory and the autumn projections are those applicable before the revision; however, growth rates are based on the new calculations after the revision.

With regard to the price of EU emission allowances, the scenarios are based on slightly rising prices, reaching €42 per EUA in 2035 (in real terms, based on 2013 prices). The same EUA prices are used for the projections under the with-measures and with-additional-measures scenarios.

See Chapters 2.1 to 2.6 of the 2017 Projections Report for further information.

5.3.2 Sensitivities

To be able to evaluate the results, the sensitivity of the assumptions on demographic and economic trends was analysed. To that end, the assumed economic growth was increased and the decline in the population decreased in both the with-measures and with-additional-measures scenarios. For both scenarios, the calculation showed that the economic variables (economic growth and energy intensity) are the predominant driving factors. Greater economic growth increases emissions under both scenarios by up to 25 Mt CO₂e in 2035. By contrast, a change in the assumptions on population trends results in only a minimal change of up to 4 Mt CO₂e by 2035. Overall, however, the effect is minor, especially by 2020, when the differences are lower than one percentage point (see Table 15 below).

In addition, the effect of a long-term low price level for energy sources and CO₂ emission allowances in the electricity sector was calculated. The current price level for both is well below all the projections of previous years. Here again, the effect is minimal: the assumptions do not result in any significant change in emissions from electricity generation. What is decisive here is that the merit order in electricity production does not fundamentally change because, as a result of the low CO₂ prices, the costs of lignite are still lower than coal, which in turn are lower than natural gas. Finally, as in the 2015 Projections Report, the effect of lower electricity exports under the WAMS scenario was examined, which results in a considerable reduction of 36 Mt CO₂e in 2020.

	WMS	WAMS
Reduction compared to 1990		
Standard key data	-34.7 %	-35.5 %
Stronger economic growth	-33.7 %	-34.5 %
Stronger population growth	-33.8 %	-34.7 %
Low energy and CO ₂ prices	-34.6 %	-35.5 %
Lower electricity export balance	-37.5 % ¹⁶³	-38.4 %

Table 16: Trends in total greenhouse gas emissions in 2020 for the sensitivity analyses under the WMS and WAMS¹⁶⁴

¹⁶² Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

¹⁶³ The effect was only actually modelled for the WAMS. Due to the very similar effect, it was assumed to be the same for the WMS.

¹⁶⁴ Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (2017).

6 Financial support and technology cooperation

6.1 Climate finance

6.1.1 General principles and assumptions

Engagement in climate action is an integral part of Germany's development policy and vice versa. The impacts of increasing climate change are directly affecting the living conditions and development opportunities of all people. Growth and development strategies must include greenhouse gas neutrality and decarbonisation of the economy as an imperative. With regard to supporting developing countries in climate change adaptation and mitigation, Germany considers the implementation of the Paris Agreement and Agenda 2030 to be closely linked.

The German government therefore supports developing countries and emerging economies in aligning their national policies with all dimensions of sustainability. Revising national development strategies, including financial policy, and establishing efficient monitoring structures are at the heart of Germany's capacity development efforts. In these efforts, the cooperation with emerging economies/global development partners is strongly focused on climate change and environmental issues.

In its delivery of climate finance, the German government is aligning itself with the decisions of the Parties to the United Nations Framework Convention on Climate Change and with the agenda to increase the effectiveness of development cooperation that is part of the Paris-Accra-Busan process.

6.1.2 Overview of climate finance 2013–2016

The German government stands to its financial obligation and has further increased its finance up to 2016 to support developing countries in their efforts to reduce greenhouse gas emissions (GHGs), adapt to the impacts of climate change and protect forests and biodiversity (including REDD+) until 2016. The Government is aiming to double its international climate finance from the 2014 target value of EUR two billion to EUR four billion by 2020 (from budgetary sources and grant elements of development loans), thus fulfilling the commitment Chancellor Merkel made in 2015.

German Climate Finance 2016 from budgetary sources by departments

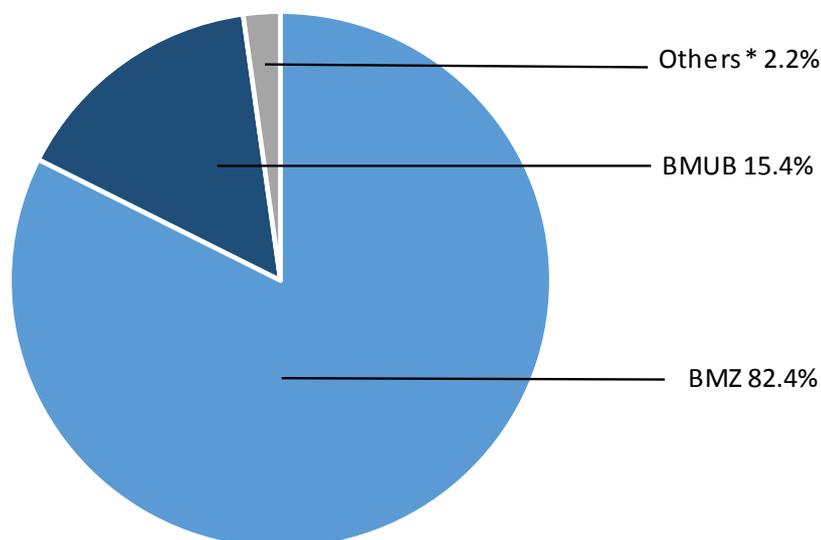


Figure 29: German climate finance for 2016 from budgetary sources, broken down by ministry in percentages (*BMBF, BMWi, Federal Foreign Office)¹⁶⁵

In 2016 Germany provided budgetary resources amounting to EUR 3.362 billion (USD 3.719 billion) for international climate finance.¹⁶⁶ This represents an increase of 25.3 % compared with the previous year (2015: EUR 2.684 billion/USD 2.977 billion). In addition, it pledged EUR 5.172 billion (USD 5.721 billion) in mobilised public finance from capital resources (c.f. definitions on page 137) through KfW Development Bank and Deutsche Investitions- und Entwicklungsgesellschaft mbH (DEG). In total, public climate finance ran to around EUR 8.534 billion or USD 9.44 billion (2015: EUR 7.406 billion/USD 8.192 billion).

In addition, steady growth can be observed when extending the observation period to include 2013 with EUR 1.950 billion (USD 2.652 billion) and 2014 with EUR 2.344 billion (USD 3.110 billion). In total, Germany has increased its contribution to climate finance sevenfold since 2005. The growth in Germany's climate finance also reflects the successful mainstreaming of climate-related issues in its development cooperation efforts.

¹⁶⁵ Own illustration, BMZ.

¹⁶⁶ The conversion of euros to US dollars in this chapter was done using the official OECD-DAC exchange rates for the year in question. 2013: EUR 0.753 = USD 1; 2014: EUR 0.754 = USD 1; 2015: EUR 0.902 = USD 1; 2016: EUR 0.904 = USD 1.

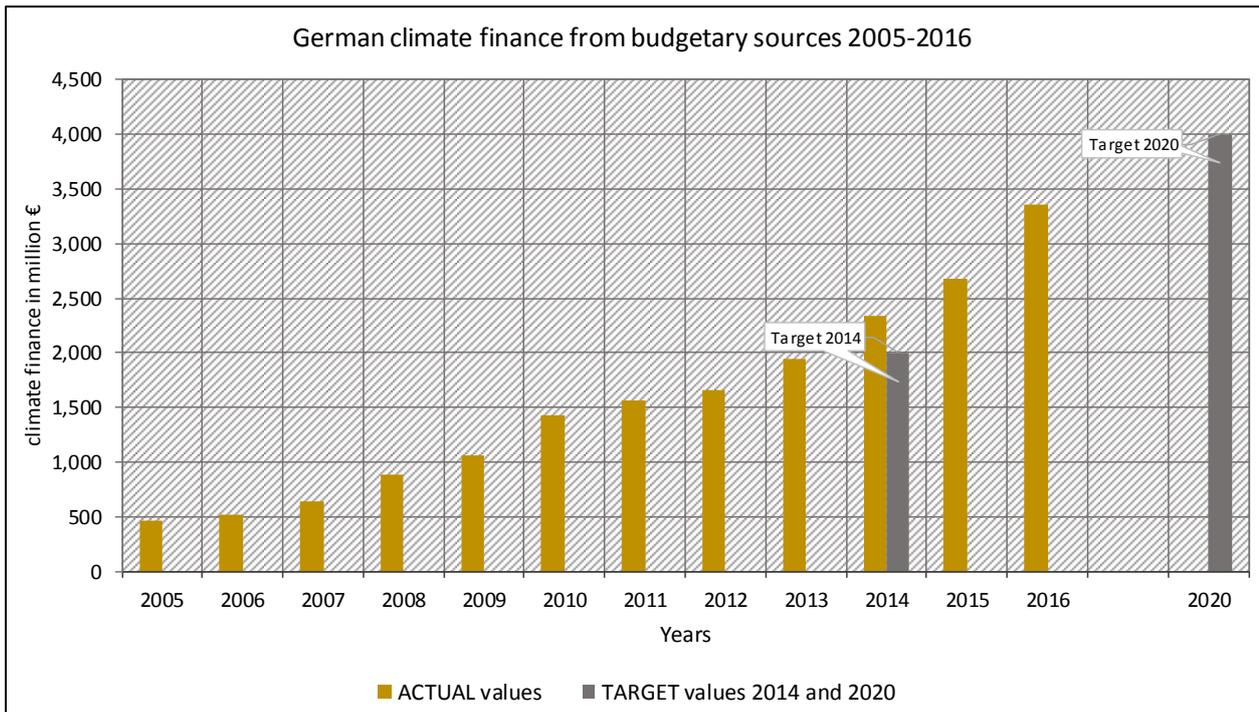


Figure 30: German climate finance from public budgetary sources 2005–2016 (in millions of euros)¹⁶⁷

6.1.3 German climate finance instruments, institutions and initiatives

The German government uses a broad range of instruments and institutions for its international cooperation activities in the field of climate and development:

- Bilateral financial, technical and academic cooperation. German climate finance focuses on bilateral cooperation with 83.8 % of the budgetary resources allocated to climate finance being spent in this way in 2016. From 2013 to 2016 that figure was around 86 %.
- Multilateral cooperation, such as the Green Climate Fund, the Climate Investment Funds, the Adaptation Fund under the Kyoto Protocol, the Global Environment Facility and the Forest Carbon Partnership Facility as well as cooperation with multilateral development banks and United Nations organisations.

During the reporting period for the National Communication, Germany set important priorities by instigating and/or providing comprehensive support for international initiatives. These priorities have supported the successful conclusion of the Paris Agreement and should now advance its rapid and ambitious implementation. Noteworthy in these efforts are the NDC Partnership (see section 6.2.1), the G7 climate risk insurance initiative InsuResilience (see section 6.3.3), the Africa Renewable Energy Initiative (AREI) (see section 6.3.4.5), the NAMA Facility and the AFR100 initiative (see section 6.3.4.5 and 6.3.4.3).

¹⁶⁷ Own illustration, BMZ.

6.1.4 Methodology used to measure German climate finance

Germany attaches great importance to measuring and communicating its climate finance transparently and comprehensively. For this reason, it has reported its bilateral climate finance in Table 7b on a project-specific basis in order to depict the individual projects in as much detail as possible. In addition, supplementary information can be found on the BMZ,¹⁶⁸ BMUB¹⁶⁹ and BMBF¹⁷⁰ websites on the individual projects.

Since 2013 Germany has been reporting on its total public climate finance, including mobilised climate finance. Since 2015 it presents the mobilised public climate finance by project in detail.

Germany distinguishes between two sub-categories of public climate finance:

- a) Climate finance from budgetary sources, including grant equivalents of development loans that include budgetary sources. Climate finance provided from the public budget is recorded in this category. In the 2014 report, the imputed climate-relevant contributions to the funds of the MDBs were recorded for the first time using the methodology developed by the Organisation for Economic Co-operation and Development (OECD) Joint ENVIRONET and WP-STAT Task Team to Improve Rio Markers, Environment and Development Finance Statistics. The grant elements of development loans will be recorded in future as soon as data are available.
- b) Mobilised public finance is the climate-related loan finance from KfW Development Bank's market funds and DEG's own resources. It predominantly comprises finance streams that count as official development assistance (ODA), as a rule in the form of concessional loans.

To ensure transparent records of climate finance, Germany has been using OECD climate markers, also known as Rio markers, since the 2011 reporting year.¹⁷¹

They are presented with a differentiation between different areas: reduction of greenhouse gases, adaptation to climate change and forest and biodiversity conservation, including REDD+. So far there are no individual international markers for REDD+.

Technology transfer and capacity building are components of virtually all of the German government's bilateral cooperation projects and cannot be categorised separately.

The statistical data in Tables 7, 7a and 7b in the Annex to this document contain the funds allocated from public budgetary sources for all climate-related bilateral development cooperation projects that were approved in the year in question.

In the case of contributions to multilateral climate finance, the year in which the funds are actually paid out is the basis for the listing.

¹⁶⁸ www.bmz.de/climatefinance

¹⁶⁹ www.international-climate-initiative.com/en/projects

¹⁷⁰ <https://www.fona.de/en/index.php>

¹⁷¹ The Rio markers are scored differently depending on the project's objective. If the mitigation of greenhouse gases or adaptation to climate change are a main goal, the project would receive the corresponding Rio marker 2. The result is that 100 % of the financing volume is allocated to the respective climate area. If mitigation or adaptation is only a secondary objective, the Rio marker is scored as 1 and 50 % of the finance volume is allocated to the particular climate area. Projects that receive the marker 0 make no significant contribution to climate change mitigation or adaptation. They therefore also show no climate-relevant finance volume. The scores of both climate markers awarded for a project may not exceed 2. For example, a project that has "mitigation of greenhouse gases" as its principal objective (score of 2) cannot have "adaptation to climate change" as a secondary objective (score of 1). However a score of KLA 1 and KLM 1 is possible. This ensures that projects are not counted more than once for climate finance.

Germany's climate-related ODA for 2013 amounted to EUR 3.444 billion (USD 3.821 billion) (EUR 3.154 billion/USD 3.499 billion bilaterally and EUR 290 million/USD 322 million multilaterally). For 2014, Germany's climate-related ODA amounted to EUR 6.306 billion (USD 6.634 billion) (EUR 5.977 billion (USD 6.269 billion) bilateral and EUR 329 million (USD 365 million) multilateral). For 2015, Germany's climate-related ODA amounted to EUR 5.077 billion (USD 5.632 billion (EUR 4.687 billion (USD 5.199) billion bilateral and EUR 390 million (USD 433 million) multilateral). There were no figures for 2016 at the time of preparation of the National Communication. The climate-related ODA deviates from the German climate finance described here. This is because KL-1 projects are counted differently. The OECD counts 100 % of the climate finance regardless of whether climate change mitigation or adaptation is a principal or secondary objective. With regard to KL-1 projects, like many other donors, Germany counts only 50 %, since KL-1 projects support climate aspects as a secondary objective. Furthermore, the time at which data are recorded varies. The basis of reporting to the UNFCCC for efforts funded by the BMZ budget is the date of government approval. BMUB reporting is based on the commissioning/conclusion of the contract. However, the ODA notification is carried out at the time of the commissioning/conclusion of the contract in accordance with the OECD definition of "commitment."

The climate-related share of other official flows (OOFs) for 2015 amounted to EUR 145.4 million or USD 161.2 million (EUR 145.4 million bilateral and EUR 60,000 multilateral). The climate-related share of funds comprising ODA and OOF totalled EUR 18.5 million.

Since the OECD Research Collaborative on Tracking Private Climate Finance was established, Germany has been intensively supporting the development of methods for recording private climate finance. In parallel to climate-specific forums, the reporting of mobilised private finance is also being driven by the OECD Development Assistance Committee (DAC). As part of the modernisation of the DAC framework at the end of 2014, DAC initiated a process to develop an international standard for measuring the direct mobilisation of private capital through public development finance. It developed instrument-specific recording methods for the mobilisation of private capital within this framework. Pilot surveys were carried out in 2015 and 2016. Starting in reporting year 2016, the OECD DAC data survey has regularly included the direct mobilisation of private capital. Up to now, the methodology has covered syndicated loans, guarantees, collective investment instruments, credit lines and direct investments. Indirect mobilisation impacts resulting from the facilitation of enabling environments, feed-in tariffs, project preparation or policy advice have not been depicted up to now. The development of other methods is planned in order to comprehensively present the mobilisation results. As part of an OECD technical background document¹⁷² for the "Roadmap to US\$100 billion", the amount of the attributed private co-finance was estimated at EUR 12.5 billion (USD 16.6 billion) based on the public climate finance deployed by industrialised countries in 2014 (bilateral and multilateral). An exact breakdown by individual country has not yet been carried out.

Germany currently reports on mobilised private climate finance only in those areas in which there are already agreed reporting methods. Using the DAC methodology, mobilised private climate finance amounted to EUR 357 million in 2015 for KfW Development Bank. The 2016 commitments are expected to be published at the end of 2017. DEG is mandated to work with the private sector. Mobilised private climate finance through DEG loans or equity participation is determined based on the overall investment sums of the projects, from

¹⁷² OECD (2016), 2020 Projections of Climate Finance towards the USD 100 billion goal: Technical Note, OECD Publishing.

which finance from public actors, primarily public development banks, is subtracted. The private finance comes primarily from DEG customers, that is investors/sponsors or private banks. The details on private climate finance are incomplete to the extent that they do not take many other possible forms of mobilisation into account. The German government is currently working on internationally agreed criteria for recording the climate finance made possible through government guarantees (Euler Hermes).

6.2 Support for Nationally Determined Contributions and the NDC Partnership

Through a range of measures from various ministries, the German government is supporting the implementation of planned national climate pledges in the partner countries (known as Nationally Determined Contributions or NDCs), which were agreed to by the Parties to the Paris Agreement. It has already supported around 40 countries in the development of their Intended Nationally Determined Contributions (INDCs) in the run-up to the Paris Agreement's entry into force.

6.2.1 NDC Partnership

In order to quickly and effectively commence the implementation of the NDCs and contribute to raising climate ambition, BMZ and BMUB, in conjunction with the Moroccan COP Presidency, other industrialised countries and developing countries, the World Resources Institute (WRI) and various international institutions, launched a global partnership to promote the implementation of NDCs at the beginning of 2016 (the NDC Partnership or NDCP).¹⁷³ This is currently being supported by a range of donors and is already working through a secretariat. The aim of the partnership is to support developing countries in bringing together their national climate contributions and development goals (NDCs and SDGs) and to help in deploying the respective bilateral and multilateral donor programmes in a more coordinated way for implementation.

About 80 countries and international organisations and development banks are currently members of the NDC Partnership.¹⁷⁴ The NDC Partnership is in principle open to all countries and international organisations that support its objectives and principles.¹⁷⁵ Thomas Silberhorn (Parliamentary State Secretary at BMZ) and Nezha El Ouafi (Secretary of State at the Ministry for Energy, Mines and Sustainable Development in Morocco) serve as Co-Chairs of the Partnership.

6.3 Channels for delivering German climate finance (allocation channels)

6.3.1 Bilateral cooperation

A large proportion of Germany's climate finance contributions come in the form of bilateral cooperation.

¹⁷³ <http://www.ndcpartnership.org/> .

¹⁷⁴ <http://www.ndcpartnership.org/partners> - as at 10.08.2017.

¹⁷⁵ Such as: support country-driven processes, promote long-term climate action, enhance efficiency and responsiveness, build in-country capacity, improve coordination, enhance integration into national planning, advance adaptation and mitigation, align development and climate change, support multi-stakeholder engagement.

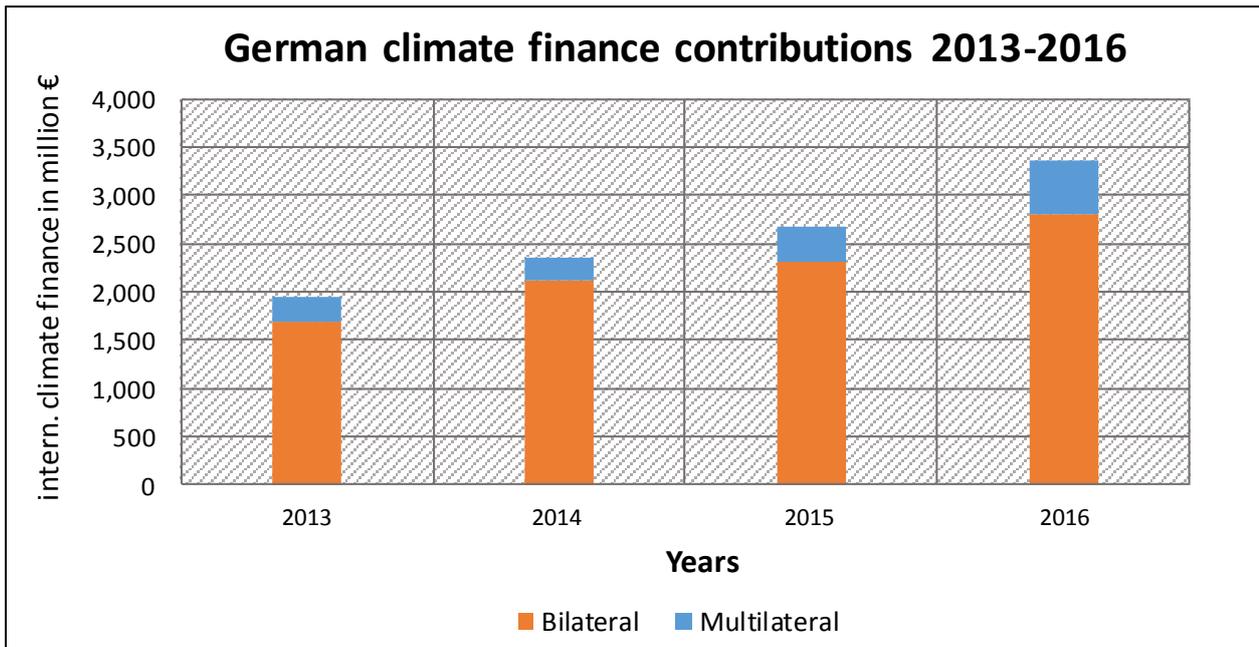


Figure 31: German climate finance contributions from budgetary sources for 2013–2016 divided into bilateral and multilateral (in millions of euros)¹⁷⁶

The aim of the German government is to be even-handed in providing climate finance for emission reduction and climate change adaptation (Figure 31). Of the budgetary funds provided from the federal budget, 55 % was used for mitigation measures and 45 % for adaptation measures in 2016. Over the entire period 2013–2016, the distribution was as follows:

¹⁷⁶ Own illustration, BMZ.

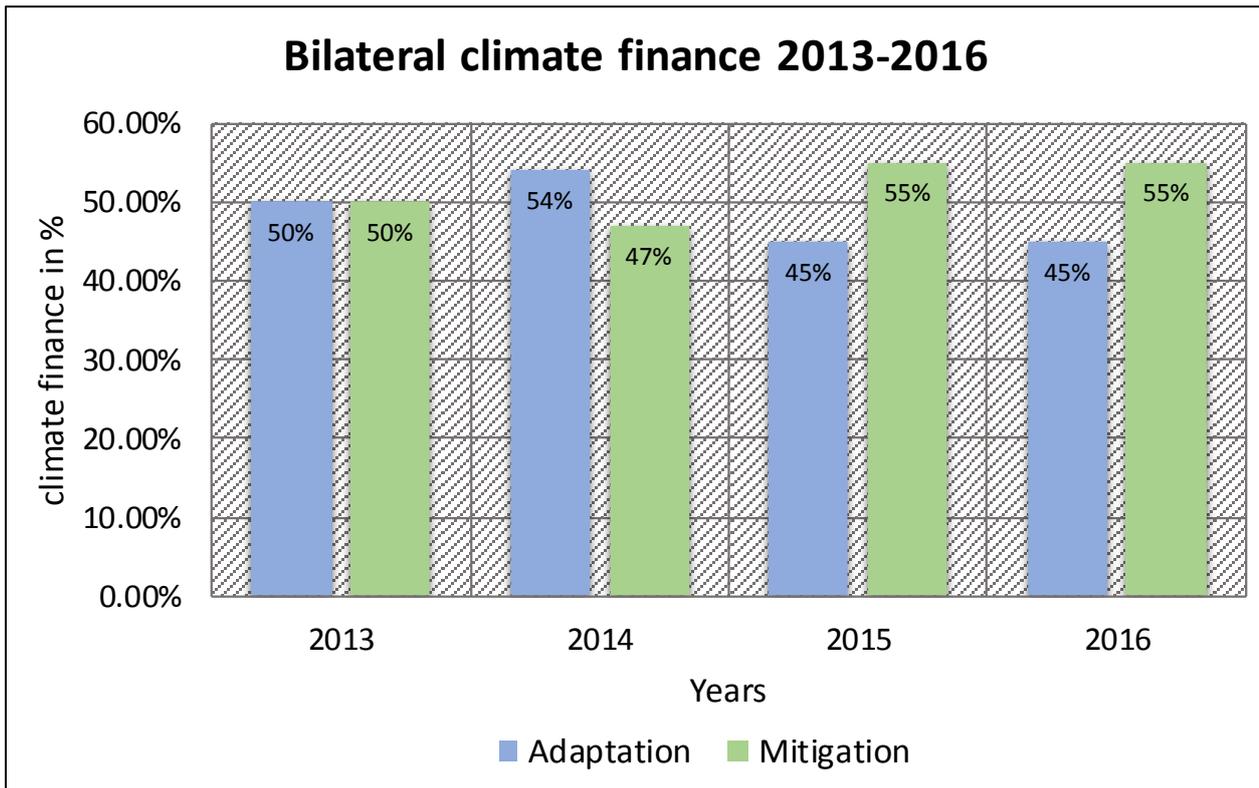


Figure 32: German bilateral climate finance from budgetary sources for 2013–2016, divided into adaptation and mitigation (in percent)¹⁷⁷

Since 2013, in addition to public climate finance from budgetary sources, Germany also reported on mobilised public climate finance, i.e. climate-related credit financed by KfW Development Bank and Deutsche Investitions- und Entwicklungsgesellschaft mbH (DEG), which uses market funds. Since 2015, this reporting has been carried out by project in detail. In addition to the deployed budgetary funds, an additional EUR 5.172 billion (USD 5.721 billion) were pledged by KfW and DEG from capital market funds in 2016.

¹⁷⁷ Own illustration, BMZ.

Mobilized public climate finance without budgetary sources 2016

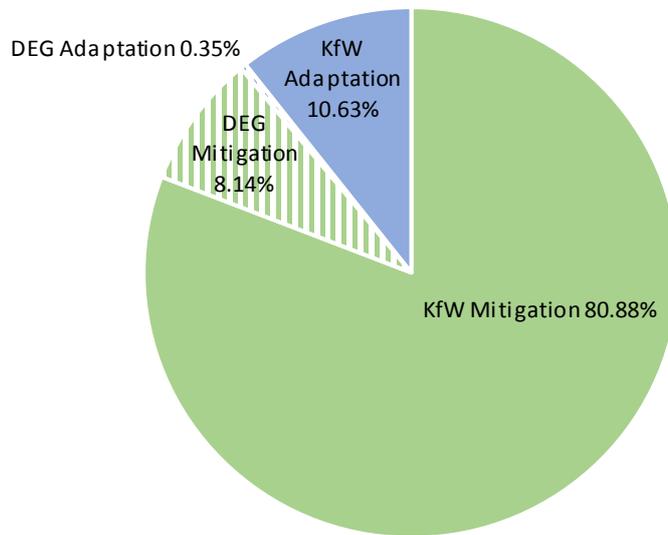


Figure 33: German finance from mobilised public market funds for 2016 (in percent)¹⁷⁸

Regional distribution: in 2016, Germany supported partner governments in Africa with EUR 946 million (USD 1,046.5 million), in the Asian, Middle East and South-East European regions with EUR 886 million (USD 980.1 million), in Latin America and the Caribbean region with EUR 372 million (USD 411.5 million) and through global projects with EUR 614 million (USD 679.2 million) (see figure 33). In 2015, Germany spent EUR 957 million (USD 1,062 million) for partnerships with African partner governments, EUR 688 million (USD 763.4 million) in the Asian, Middle East and South-East European regions, EUR 348 million (USD 368 million) in Latin America and the Caribbean and EUR 314 million (USD 348 million) in global projects (cf. figure 33).

¹⁷⁸ Own illustration, BMZ.

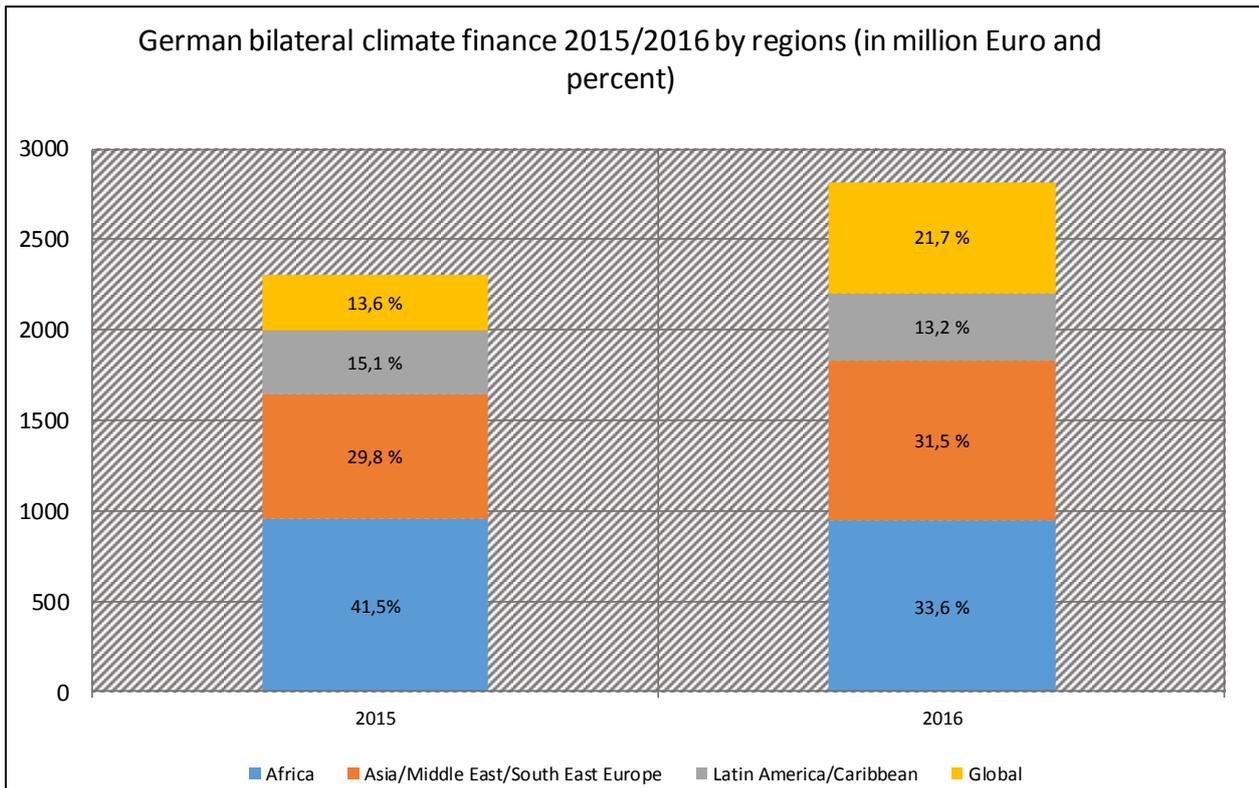


Figure 34: German bilateral climate finance 2015–2016 from budgetary sources by region (in percent)¹⁷⁹

6.3.2 Multilateral cooperation

Germany provides one portion of its climate financing through multilateral institutions as contributions to international climate funds and multilateral organisations. Germany is involved not only in its role as donor, but also supports funds and multilateral development banks with regard to their strategic orientation and operational implementation in order to optimise their contribution to making the climate finance efficient and effective .

The funds that were directly set up/operate under the United Nations Framework Convention on Climate Change and are supported by Germany include the Green Climate Fund (GCF), the Adaptation Fund (AF); the Global Environment Facility (GEF); the Least Developed Countries Fund (LDCF); and the Special Climate Change Fund (SCCF).

Germany also supports climate funds that exist independently of the Framework Convention on Climate Change: the World Bank's Climate Investment Funds (CIF), including the Pilot Programme for Climate Resilience (PPCR); and the Forest Carbon Partnership Facility (FCPF).

Germany participates in the following funds of multilateral development banks (MDBs) through its regular contributions: the International Development Association (IDA) of the World Bank, the African Development Fund (AfDF), the Asian Development Fund (AsDF) and various funds of the Caribbean Development Bank. These contributions, as well as its contributions to the GEF, are included in German climate finance in accordance with the imputed climate-relevant shares established by these institutions.

¹⁷⁹ Own illustration, BMZ.

In addition, Germany supports United Nations programmes in implementing the global climate agenda through annual contributions and special initiatives.

Organisation	2013 ¹⁸⁰	2014	2015	2016
GCF	0.8/1.0	1.0/1.3	18.1/20.1	70.8/78.3
GEF	44.3/60.3	45.1/59.8	44.3/49.1	48.7/53.9
LDCF	30.0/40.8	30.0/39.8	30.0/33.3	25.0/27.7
SCCF	19.6/26.7	18.0/23.9	3.0/3.3	-
AF	30.0/40.8	50.0/66.3	50.0/55.5	50.0/55.3

Table 17: Disbursements of multilateral climate finance in EUR million/USD million

6.3.2.1 GCF

Germany pledged EUR 750 million (USD 1.003 billion) in 2014 for the initial capitalisation of the GCF, and is thus one of the largest donors together with the USA, Japan, the United Kingdom and France. Germany also contributed EUR 785,000 (USD 1,042,244) in 2013 for the establishment of the interim secretariat and administrative costs.

Germany serves as a member of the Board of the GCF. It participates actively in Board discussions on the institutional setup and operational implementation of the Fund.

6.3.2.2 GEF

Germany paid EUR 347 million (USD 479.1 million) into the Fifth Replenishment of the GEF Trust Fund (2010–2014). Of this, around 40 % was earmarked for the climate change funding area as well as climate-related projects in other funding areas. Germany pledged EUR 350 million (USD 460.3 million) for the Sixth Replenishment (2014–2018) and is thus the third-largest donor after Japan and the USA. Ever since the GEF began publishing its imputed climate relevant share (2015), Germany has used it as a basis for calculating the GEF climate contribution.

In addition to the regular replenishment cycle, Germany provided EUR 9.94 million (USD 11 million) in 2016 for the Trust Fund for the Capacity-Building Initiative for Transparency (CBIT). The Trust Fund was set up in 2016 at the request of the Parties to the Paris Agreement.

Germany serves as a member of the GEF Council. Germany supports the strategic orientation and operational implementation of the fund through its active participation in the Council meetings and technical advisory services for project proposals. The focus here is on harnessing synergies between the conventions dealt with in the GEF and the expansion of the effective results monitoring at project and programme level.

¹⁸⁰ in millions.

6.3.2.3 LDCF

The German commitments to the LDCF amount to a total of EUR 215 million (USD 237.8 million) (as at March 2017). In the reporting period, Germany paid EUR 115 million (USD 127.2 million) into the Fund. This makes Germany the largest donor to the LDCF.

In addition, Germany is providing technical advisory services on LDCF priorities, for example on innovative approaches in climate risk management, and also advising the Fund on designing project proposals. In this work, Germany is able to draw on its experience at country level to contribute to the strategic orientation and further development of the LDCF.

6.3.2.4 SCCF

In total, Germany's commitments to the SCCF amount to EUR 90 million (USD 99.6 million) (as at March 2017). In the reporting period, it paid EUR 40.6 million (USD 44.91 million) into the Fund. This makes Germany the largest donor to the SCCF.

Germany concentrates its support for the SCCF on adaptation to climate change and provides advice on designing project proposals.

6.3.2.5 Adaptation Fund

Since 2013 Germany has paid a total of EUR 180 million (USD 199.1 million) into the Fund and thus supports adaptation projects worldwide.

In addition, Germany serves as a member of the Board, which is based in Germany. Through its active participation on the Board, Germany supports the strategic orientation as well as the operational implementation of the Fund.

6.3.2.6 Other multilateral climate funds

World Bank Climate Investment Funds (CIFs)

The German contribution to the CIFs amounts to a total of EUR 550 million.

The Clean Technology Fund (CTF) is currently endowed with approx. EUR 5.06 billion (USD 5.6 billion). With its contribution of EUR 500 million (approx. USD 615 million) in the form of a loan, Germany is the fourth largest donor (as at October 2016). It is estimated that CTF funds will leverage over EUR 41.6 billion (USD 46 billion) in cofinancing; the private sector is the largest funder at over EUR 13.6 billion (USD 15 billion) (leverage 1:3.7), followed by the MDBs (1:2.6) and bilateral/other sources (1:2). BMZ has participated actively in CIF work since 2008 in its semi-annual meetings and is a member of the Trust Fund Committee (TFC).

Furthermore, Germany is supporting the Pilot Program for Climate Resilience (PPCR), a sub-programme of the Strategic Climate Fund (SCF), with a grant of EUR 50 million (USD 55.3 million). In addition to the financial contributions, Germany has participated actively in the work of the PPCR through strategic advisory services and recommendations since 2008. BMZ serves as a member of the PPCR Sub-Committee.

Forest Carbon Partnership Facility (FCPF)

Germany is a co-initiator of the FCPF (2007 G8 summit in Heiligendamm) and has since been the second largest donor after Norway and ahead of the United Kingdom with overall commitments of EUR 210.4 million (USD 232.7 million) (of which EUR 200.4 million (USD 221.7 million) is from BMZ and EUR 10 million (USD 11 million) is from BMUB); in total the

FCPF currently has a budget of around EUR 997 million (approx. USD 1.1 billion). Germany has paid in EUR 141.4 million (USD 156.4 million) for the period 2013–2016.

The FCPF is key in piloting and implementing the REDD+ climate instrument. In September 2014 as part of the New York Declaration on Forests, Germany announced it would contribute to ending global forest loss by 2030. With its sub-funds, the Readiness Fund and the Carbon Fund, FCPF is a central implementation instrument for this purpose. The Readiness Fund has supported a total of 45 countries so far in establishing, through a participatory process, a technical and political framework for implementing REDD+ (including the participation of civil society, national strategy, monitoring of forest areas). The Carbon Fund ensures the results-based financing of the national forest programmes.

Multilateral financial institutions

Germany cooperates closely with multilateral financial institutions on climate change mitigation and adaptation. It facilitates intensive work by institutions on climate issues through capital contributions, regular contributions to funds of multilateral financial institutions and climate-specific trust funds. In addition, Germany promotes close cooperation with institutions in multilateral initiatives and partnerships (such as the above-mentioned NDC Partnership). In the executive bodies, Germany actively supports climate-related topics and clearly advocates a climate-oriented agenda.

In addition to multilateral development bank funds, the development banks themselves support the partner countries with substantial resources, which are refinanced on the international capital market (mobilised public climate finance, similar to KfW climate finance, for example). Reporting on non-concessional climate finance provided by multilateral development banks would need to be reported in a form that has been coordinated with other donors. In 2016 the multilateral development banks jointly mobilised USD 25.5 billion in public climate finance (according to the banks' own calculations in the 2016 Joint Report on Multilateral Development Banks' Climate Finance, published in September 2017). As a major shareholder of the banks, Germany contributed a great deal to this.

Organisation	2013 ¹⁸¹	2014	2015	2016
World Bank (IDA)	68.5/ 93.2	130.2/172.8	109.7/ 121.7	96.8/107.1
African Development Bank (AfDF)	65.2/88.7	56.2/74.6	56.5/62.7	36.9/ 40.8
Asian Development Bank (AsDF)	23.4/31.8	14.1/18.7	7.0/7.8	5.7/6.3
Caribbean Development Bank (CDB) ¹⁸²	-	-	-	-

Table 18: Selected imputed climate relevant shares on core contributions in millions of EUR/USD

¹⁸¹ in millions.

¹⁸² No imputed share available that is applicable to concessional funds.

Organisation	Germany's share (percentage) of the total capital	Germany's share of the total capital in EUR billion	Of which: paid-in capital
World Bank Group (IBRD, IFC, MIGA)			
IBRD	4,38 %	€11.05 billion	€0.68 billion
IFC	4,77 %	€0.12 billion	N.A.
MIGA	4,20 %	€0.92 billion	€0.02 billion
African Development Bank	4,15 %	€3.42 billion	€0.20 billion
Asian Development Bank	4,33 %	€5.86 billion	€0.29 billion
Inter-American Development Bank	1,90 %	€3.08 billion	€0.11 billion
European Bank for Reconstruction and Development	8,52 %	€2.56 billion	€0.53 billion
European Investment Bank	16,11 %	€39.20 billion	€3.50 billion
Asian Infrastructure Investment Bank	4,48 %	€4.05 billion	€0.81 billion
Caribbean Development Bank	5,58 %	€0.10 billion	€0.02 billion

Table 19: German capital share in multilateral financial institutions

In addition to capital contributions and funds for regular replenishment cycles of concessional financing, Germany contributes additional subsidies for climate-specific trust funds in multilateral finance institutions. Between 2013 and 2016 its contributions to these funds amounted to EUR 350.7 million (USD 387.9 million).

Organisation	2013	2014	2015	2016
World Bank				
<ul style="list-style-type: none"> Global Facility for Disaster Reduction and Recovery 	-	1.70/2.26	0.25/0.28	-
<ul style="list-style-type: none"> Forest Carbon Partnership Facility 	30.20/41.08	47.00/62.36	12.40/13.75	51.80/57.30
<ul style="list-style-type: none"> NDC Partnership Support Facility 	-	-	-	10.00/11.06
<ul style="list-style-type: none"> Pilot Auction 	-	15.00/19.90	-	-

Facility for Methane and Climate Change Mitigation				
• Action for Fair Production	-	-	-	0.50/0.55
• Energy Sector Management Assistance Program (ESMAP)	-	-	0.90/1.00	7.15/7.91
• Pollution Management and Environmental Health (PMEH) program	-	-	-	8.00/8.85
• Multi-Donor Trust Fund for the Extractives Global Programmatic Support (EGPS)	-	-	0.28/0.31	-
• BioCarbon Fund Initiative for Sustainable Forest Landscapes	125.00/170.02	35.50/47.10	-	-
Inter-American Development Bank				
• Green Finance Facility	-	-	-	5.00/5.53
European Bank for Reconstruction and Development				
• Eastern Europe Energy Efficiency and Environment Partnership Fund	1.00/1.10	13.00/14.30		-

Table 20: Payments to climate-specific trust funds in multilateral institutions in EUR million/USD million

Specialised United Nations bodies

Germany also pays annually into designated United Nations programmes to boost expertise and develop capacities in selected areas. See common tabular format (CTF) Tables 7a and 7b for a list of the supported United Nations programmes for the four years covered by this National Communication.

Germany also provides funding for initiatives, fiduciary funds and knowledge centres. Between 2013 and 2016 German support amounted to EUR 68.0 million (USD 75.2 million).

Through these initiatives, Germany is strengthening capacity building in developing countries on the implementation of climate change mitigation and adaptation measures, increased climate transparency and measures for implementing the Montreal Protocol (see table 20).

In addition, it annually supports the activities of the UNFCCC secretariat as well as climate-related knowledge generation in several institutions. From 2013–2016, Germany supported the UNFCCC secretariat with EUR 22.84 million (USD 25.27 million) in compulsory and voluntary contributions.

Organisation	2013	2014	2015	2016
United Nations Development Programme				
• UNDP Equator Initiative	0.05/0.07	-	-	0.38/0.42
• Biodiversity Finance Initiative	-	10.00/13.27	-	-
United Nations Environment Programme				
• UNEP Collaborating Centre for Climate and Sustainable Energy Finance	0.75/1.02	0.40/0.53	0.30/0.33	0.20/0.22
• Thematic Trust Fund - Capacity Development for IPBES through BES-NET and the SGA Network	-	-	4.50/4.99	-
United Nations Framework Convention on Climate Change (UNFCCC)				
• United Nations Framework Convention on Climate Change (UNFCCC)	5.58/7.59	6.10/8.09	6.10/6.77	5.08/5.62
United Nations Office for Project Services				
• MRV Trust Fund	-	-	6.76/7.50	-
• Sustainable Energy for All - Global Facilitation Team	0.25/0.34	-	-	0.60/0.66
• Cities Alliance	0.50/0.68	-	0.50/0.55	-
• United Nations Human Settlements Programme (UN-HABITAT)	-	1.60/2.12	-	-
Other				
• Montreal Protocol	7.80/10.61	8.00/10.61	14.46/16.04	11.17/12.36

• IPCC	0.29/0.40	0.29/0.39	0.30/0.33	0.29/0.32
• IRENA	-	-	6.28/6.97	6.78/7.50
• World Resources Institute (WRI): NDC Partnership: partnership to accelerate implementation of nationally determined climate and development actions	-	-	-	7.96/8.81
• World Health Organization (WHO): Special Programme for Research and Training in Tropical Diseases (TDR)	-	-	0.43/0.48	0.38/0.42
• Food and Agriculture Organization of the United Nations (FAO): Mitigation of Climate Change in Agriculture (MICCA) Project (part of the Bilateral Trust Fund for Food Security Germany/FAO)		2014–2017: 1.78		
• World Food Programme (WFP): several projects	-	0.13/0.17	-	39.51/43.71

Table 21: Contributions paid to specified United Nations bodies and trust funds of United Nations organisations in EUR/USD millions

6.3.3 Methods, assumptions, approaches to adaptation to climate change

Germany attaches great importance to supporting developing countries in adapting to climate change. It sees it as an international responsibility and has made it one of the four integral pillars of the German Strategy for Adaptation to Climate Change (2008).

The German government strives to provide balanced support for mitigation and adaptation. In 2014 the adaptation share of bilateral climate finance from the federal budget was 53.37 % (approx. EUR 1 billion (USD 1.3 billion)). Accordingly, the contribution for mitigation was 46.63 % (EUR 877 million (USD 1.164 billion)). In 2015 these figures were 55.22 % (EUR 1.3 billion (USD 1.4 billion)) and 44.78 % (EUR 1 billion (USD 1.1 billion)). In 2016 the adaptation share of bilateral climate finance from the federal budget was 45.86 % (EUR 1.55 billion (USD 1.71 billion)). Accordingly, the contribution for mitigation was 54.14 % (EUR 1.83 billion (USD 2.02 billion)).

The priority areas of the German Ministry for Economic Cooperation and Development's (BMZ) support are ecosystem-based adaptation (EbA) and adaptation of agricultural production and food security, water management and adaptation, risk management instruments in connection with climate change impacts, for example through innovative insurance solutions, and the development and implementation of national adaptation strategies in the context of countries' National Adaptation Plans (NAP) and Nationally Determined Contributions (NDCs). In addition to the relevant BMZ projects and programmes, the International Climate Initiative (IKI) also contributes to German climate finance for adaptation. Overall, German climate finance in this area is directed at the needs of particularly vulnerable countries and groups.

Management of climate risks – disaster preparedness

Disaster preparedness aims to reduce climate change risks and limit damage. As a signatory to the Sendai Framework for Disaster Risk Reduction, Germany supports developing countries in their endeavours to take precautions to protect critical infrastructure such as schools, hospitals and power stations. Innovative insurance schemes that provide cover against extreme weather events offer the option of transferring risks and provide financial support to households and businesses forced to start afresh after a natural disaster. As an initiator of and donor to various such insurance schemes, BMZ plays a strong pioneering role in climate risk management.

Germany's financial cooperation activities fund efforts such as hydrological monitoring networks, multi-purpose shelters and the initial phase of risk management systems at country level.

Climate risk insurance initiative – InsuResilience

At the impetus of BMZ, the climate risk insurance initiative InsuResilience was launched under the German G7 Presidency in 2015. The aim of the initiative is to create access to direct or indirect insurance against climate risks for up to 400 million additional poor and vulnerable people in developing countries by 2020. Innovative insurance solutions aim to promote the financial security of the people, and a systematic risk assessment works to raise awareness of climate risks. This facilitates more effective support for the development of adaptation activities and associated risk preparedness measures in the most at-risk countries. So far, BMZ has contributed EUR 190 million (USD 208 million) and has provided a headquarters for the InsuResilience secretariat in Bonn.

Drought insurance for African countries – the African Risk Capacity (ARC)

The African drought insurance African Risk Capacity (ARC), founded with the support of BMZ and DFID (United Kingdom's Department for International Development), will be expanded systematically under InsuResilience. BMZ supported ARC in 2013–2016 with EUR 102.2 million (USD 113.05 million).

With the help of InsuResilience funds, new insurance products against floods and strong winds are planned to supplement existing drought insurance. An insurance claim was already made in 2015 in which approximately EUR 23.44 million (USD 26 million) was paid out to Mauritania, Niger and Senegal, countries which suffered a severe drought.

Pacific Catastrophe Risk Assessment and Financing Initiative Facility (PCRAFI)

In 2016 Germany founded PCRAFI on the Cook Islands as an independent indirect insurance facility together with partners from the Pacific region, USA, Japan and the United Kingdom and with support from the World Bank.

The Pacific countries participated actively in setting up the facility. PCRAFI offers policies insuring against cyclones, earthquakes and tsunamis. The G7 contribution amounts to EUR 31.64 million (USD 35 million), of which BMZ alone provides EUR 15 million (USD 16.6 million). For example, BMZ provided Vanuatu and other affected neighbouring states with EUR 6 million (USD 6.7 million) through its Emergency Relief after Cyclone Pam project.

Furthermore, the Munich Climate Insurance Initiative (MCII) supported several Caribbean countries in disseminating direct insurance products that had already been developed for particularly vulnerable population groups.

InsuResilience Investment Fund (previously Climate Insurance Fund)

As part of the G7 InsuResilience initiative, the Fund aims to increase the capacities of poor and vulnerable people in developing countries to adapt to climate change and cope with its impacts by improving the range and uptake of extreme weather insurance policies. These help reduce the resulting costs and associated financial and, in some cases, existential risks for those affected. In order to achieve this, the Fund provides commercial equity and debt financing to insurance companies and the intermediaries that work with them (e.g. brokers or financial institutions). This is accompanied by financing of advisory and training measures on developing needs-based insurance policies, on designing simple, comprehensible and fair insurance policies based on responsible finance principles and, if needed, measures to promote the financial literacy of policyholders. In 2013 BMZ contributed EUR 18.7 million (USD 24.8 million), in 2014 EUR 48.9 million (USD 64.88 million) and in 2016 EUR 7.2 million (USD 7.96 million).

Support for the most vulnerable countries

Germany provides targeted support to the most vulnerable countries in the group of least developed countries and small island developing states (SIDS); it strengthens their adaptive capacities and increases the resilience of their agricultural production and infrastructure.

Building adaptive capacities by integrating adaptation into national development planning

A key approach in BMZ's support to establish adaptive capacities is promoting the integration of climate aspects into the national development and budget planning of partner countries. Germany supports partner countries in designing their National Adaptation Plan (NAP) processes, for example. In conjunction with other countries, BMZ launched the NAP Global Network in 2014, which contributes to national and global coordination of donors in the field of climate change adaptation and acts as a communication forum for experts and government representatives.

Agriculture/food security, land degradation, sustainable land use

Agriculture is particularly affected by climate change. Without adaptation, it will not be possible to achieve the production increases on the ground that are required to feed a global population that continues to grow rapidly, and simultaneously contribute as much as possible to reducing greenhouse gas (GHG) emissions. Germany therefore strives to adapt agricultural development in partner countries to the challenges posed by climate change. The promotion of food security in rural areas and agriculture is a great concern of the German government. BMZ provides around EUR 1.5 billion annually for this purpose. Through its special One World, No Hunger initiative, BMZ makes a significant contribution to the adaptation of agriculture to climate change and sustainable resource use and thus to climate action in partner countries. Land-use changes, that is the conversion of forest into agricultural areas, make the greatest contribution to agriculture's greenhouse gas emissions.

In addition, the German Ministry of Food and Agriculture (BMEL) supports the Food and Agriculture Organization of the United Nations (FAO) in its mandate to provide technical cooperation that strengthens the member states' governments in adapting agriculture to climate change and reducing agriculture's impact on the climate as part of its food security programmes.

Furthermore, scientists working in inter- and transdisciplinary research partnerships set up by the German Ministry for Education and Research (BMBF) have developed a knowledge base on the interactions between land management, climate change and ecosystem

services as part of a funding measure on sustainable land management, which received a total of EUR 75.9 million (USD 84.0 million) in funding between 2009 and 2016. Twelve projects in Africa (Botswana, Namibia, Angola, Madagascar), Asia (China, Viet Nam, and the Philippines), South America (Brazil) and Europe (Russia, northern European coastline) analysed the complex interdependencies and developed practical strategies and measures that can be piloted and transferred to other regions. BMZ is also contributing EUR 20 million (USD 22.12 million) per year to finance 17 international agricultural research centres.

Water

Water is the medium by which climate change most directly impacts people and ecosystems as well as various industries. Climate change manifests itself in changes to water availability and quality as well as extreme weather events that have adverse impacts on food security, health and energy generation. This affects poor people in particular, whose adaptive capacity is low due to financial limitations, and can promote conflict. Water is the adaptation sector that is most often prioritised in the NDCs due to, among other things, the expected salinisation of groundwater through the rise in the sea level as well as extreme weather events and increasing water scarcity. Germany's international cooperation activities are working toward designing adaptation measures in the water sector on the basis of the projected climate change impacts in the partner countries. They include, for example, measures to save water and increase its use efficiency. Flood protection is a suitable adaptation measure in areas experiencing increased flooding. Measures to save water, such as wetlands conservation, groundwater recharge or artificial reservoirs, can lessen the increasing insecurity.

In addition to the direct impacts of climate change on the water sector, there are many intersections with other areas of action where climate change manifests itself through impacts on water resources, including agriculture (irrigation) and energy (cooling water). These climate change impacts require appropriate solutions, for example advancing the water-energy-food security nexus.

Ecosystem-based adaptation (EbA)

The projects financed by BMZ advise partner countries on integrating the EbA approach into their planning processes and implementing it. Model projects test EbA measures and compile and disseminate the results. The International Climate Initiative (IKI) invested EUR 125 million (USD 138 million) in EbA up to the end of 2016. IKI is supporting projects in Thailand, Colombia and Viet Nam, for example, which have incorporated ecosystem services as a major feature of their flood management plans.

Examples of climate change adaptation initiatives/projects

Adaptation for Smallholder Agriculture Programme (ASAP)

BMZ supported ASAP through the International Fund for Agricultural Development (IFAD) with EUR 13 million (USD 14.38 million) in 2016. The programme helps smallholders in adapting their production to the impacts of climate change. It aims to reach eight million smallholders in 30 countries by 2020.

Integrating Agriculture into National Adaptation Plans – Kenya, Nepal, the Philippines, Thailand, Uganda, Uruguay and Zambia

National Adaptation Plans are an essential tool for focused, coordinated and integrated adaptation planning. This project supports the partner countries in building the technical capacity they need to integrate important adaptation requirements for the agriculture sector into their ongoing planning and budgeting processes. To this end, experience gained in

previous or current projects funded by IKI and other donors is used to provide advisory input into policymaking processes. Furthermore, the capacity building activities are closely linked with BMZ's National Adaptation Plan Global Support Programme (NAP-GSP). The project currently has EUR 10 million (USD 11 million) in funding and a term of four years (2014–2018). Other donors can also pay into the trust fund.

Ecosystem-based adaptation (EbA) in the Caribbean

An EbA Facility, launched in 2016, provides small island states in the Caribbean with technical and financial support of EUR 25 million (USD 27.7 million) for the implementation of ecosystem-based adaptation measures. The Facility, which was set up as a sinking fund under the auspices of the Caribbean Biodiversity Fund (CBF), expands the existing endowment fund. For example, the Facility can cover the urgent need for short-term financing, particularly for small and medium-sized EbA investments (on average around USD 0.5 million to 1.5 million). The promotion of measures to protect, better use and rehabilitate coastal ecosystems relevant to adaptation (primarily coral reefs, mangroves and seagrass beds) is intended to help reduce the vulnerability of SIDS to the negative impacts of climate change.

First database worldwide that records agricultural emissions

How can you reduce the emissions of greenhouse gases in agriculture if you do not know exactly where and in what amounts they are being produced? The response to that question comes from a new database that was supported by BMEL and is integrated into the FAO statistical system. In addition, a system was set up that identifies and assesses greenhouse gas emissions and possible mitigation strategies in the countries and transfers these to the central database. On this basis, countries receive support in building capacities to minimise the damage and risks of climate change.

6.3.4 Methods, assumptions, approaches to reducing greenhouse gases

Germany supports partner countries in establishing low-emission economic and supply structures. This includes using renewable energy, increasing energy efficiency, reducing extremely climate-damaging fluorinated GHGs and sustainable urban planning. Other areas of action include developing climate-oriented mobility and waste management strategies/concepts and conservation of natural carbon sinks, in particular forests and peat bogs. The water sector can also contribute to the reduction of greenhouse gases, particularly through improved energy efficiency and the use of renewable energy sources in the extraction and distribution of water and sustainable wastewater management.

These measures also contribute to preserving progress in economic and social development - such as the success achieved in the fight against poverty, hunger, disease and for more education - which is threatened by climate change, and help to dovetail investments in climate action with the global Sustainable Development Goals. Climate change mitigation and sustainable emission reductions are therefore closely linked with development policy. For this reason, Germany believes it is a priority to support the implementation of the Paris Agreement worldwide and to support developing countries in reducing greenhouse gas emissions and promoting sustainable development.

6.3.4.1 Energy

Cooperation in the energy field is pursuing a rapid transformation of the energy sector in emerging economies and developing countries. The aim is to achieve a sustainable, needs-

based, low-emission and climate-proof energy infrastructure at all levels and thus bring together energy security and climate change mitigation.

To this end, the German government is drawing on the experience it has acquired with achieving an energy transition in Germany, and supports in particular expanding the use of renewable energy and increasing energy efficiency. Innovative solutions to utilising renewable energy sources to improve energy access and reduce energy poverty in developing countries are also taken into account. The transformation of the energy sector is supported through the provision of innovative financing instruments, investment measures, guidance on the transfer of technologies and expertise, development of institutional capacities and skills, policy advice in the partner countries, and cooperation with regional and multilateral partners.

For example, the German Ministry of Economic Affairs and Energy (BMWi) finances 27 bilateral energy partnerships with countries outside the EU with the aim of achieving an intensive regular exchange on energy policy and energy transitioning and supporting countries in their individual energy transition processes. There are regular work meetings, conferences and exchanges of information with third parties. The cooperation arrangements and advice focus on issues surrounding the dismantling of fossil fuel subsidies, the acceptance, financing and grid integration of renewable energy, the fight against energy poverty, digitalisation, diversification of the energy mix, emission reductions, foreign energy and energy supply partnerships, energy efficiency, the green economy, expansion of infrastructure, liberalisation and market design, new and sustainable drive systems and electric mobility, regulation of the market and consumer interests. In addition, Germany is advocating for a gradual phasing out of fossil fuels by 2050, especially bringing a rapid halt to coal expansion. In order to further strengthen the transformative character of German development cooperation's energy projects, the government, in line with its report on coal finance for the economic committee of the German parliament (Bericht der Bundesregierung zur internationalen Kohlefinanzierung für den Wirtschaftsausschuss des Deutschen Bundestages) from January 2015, is no longer supporting the construction of new coal-fired power stations and retrofitting of decommissioned coal-fired power stations in partner countries. Therefore, in 2015, KfW Development Bank reviewed its financing criteria for coal-fired power stations and made them more demanding. In early 2016 they were taken into account as additional criteria in the newly formulated technological and climate-related criteria in the OECD Sector Understanding on Coal-Fired Electricity Generation Projects.

Many of the programmes supported in the sector aim at improving the political, financial and technical framework in the partner countries in order to develop markets and the demand for energy services to mitigate climate change at national and local level and to enable the private sector, as a key actor, to disseminate climate-friendly technologies. Policy advice on the dismantling of direct and indirect subsidies for fossil fuels takes on greater significance in this context. Sustainable energy is one of the largest funding areas in Germany's international climate finance.

6.3.4.2 Transport

German development cooperation policy aims to increase energy efficiency in the transport sector and promote modes of transportation that have less of an impact on the environment and climate. The German government is supporting the establishment and expansion of public transport systems in developing countries and emerging economies, and also introducing regulations and measures to promote environmentally friendly passenger and

goods transport, making vehicle fleets more energy efficient and environmentally sound, for example through alternative environmentally-friendly drive technology, and improving transport planning in towns and cities.

In the context of the Habitat III process and the 2016 Paris Agreement, the German government has become significantly more engaged in sustainable and climate-friendly transport. For example, BMZ introduced the Transformative Urban Mobility Initiative (TUMI) for sustainable urban transport in developing countries and emerging economies at the third United Nations Conference on Housing and Sustainable Urban Development (Habitat III) held in Quito in October 2016. Starting in 2017, BMZ increased its worldwide support through this initiative for the establishment and expansion of sustainable mobility systems in developing countries and emerging economies. This involves investments totalling up to EUR 1 billion per year in bus routes, light rail and underground networks, footpaths and cycle paths. Furthermore, over 1,000 technical and managerial staff from ministries, city administrations and universities in developing countries and emerging economies receive basic and further training to carry out steps ranging from practical planning to the implementation of sustainable mobility. Innovative pilot projects in small and medium-sized towns and cities are also promoted through a worldwide competition.

In addition to investment measures in environmentally friendly local public transport, cycling and walking, the German government is also supporting the establishment of organisational structures and training opportunities. This includes, for example, strategic mobility planning and supporting partner countries in developing and implementing infrastructure projects. For example, it launched the Mobilise Your City (MYC) Initiative last year to promote sustainable urban mobility strategies and national urban transport policies in conjunction with French partners. Mobilise Your City is also supported by the European Commission.

6.3.4.3 Forestry and agriculture

Forestry is another important field of activity in Germany's cooperation on climate change action. The German government's international forest policy aims to halt deforestation and further forest degradation, preserve or restore forests as greenhouse gas sinks and tap into the CO₂ mitigation potential of sustainable forestry.

In the field of forest conservation, the German government primarily supports concepts that reconcile forest protection and sustainable use. It is one of the biggest donors worldwide in the area of international forest protection. Up to 2016, BMZ made available EUR 2 billion (USD 2.21 billion) for more than 200 forestry initiatives, primarily in the three largest green lungs of our planet (Amazon Basin, Congo Basin, Indonesia). Currently the support is focused on the sustainable management of forests for climate protection (REDD+) and conservation of biodiversity. The promotion of further strategic areas, such as the restoration of forest landscapes and deforestation-free supply chains, is also a BMZ priority in international forest policy. BMZ launched the African Forest Landscape Restoration Initiative (AFR100) in conjunction with the New Partnership for Africa's Development (NEPAD) and the World Resources Institute (WRI) at the 2015 Paris Climate Change Conference. The initiative aims to restore around 100 million hectares of forest landscapes in Africa by 2030 and, in doing so, also supports the implementation at regional level of the global target set by the Bonn Challenge.

An important possibility for leveraging forest conservation lies in cooperation between governments and business and the creation of sustainable enabling environments. The German government therefore promotes private sector initiatives relating to soy, palm oil, coffee and cocoa and will further strengthen its cooperation with the private sector to

establish "deforestation-free" supply chains. The aim is to provide further incentives to the agricultural sector in partner countries for forest conservation and to promote land use that is sustainable and preserves forests. At the initiative of the Netherlands, Germany also joined the United Kingdom and Denmark in signing the two Amsterdam Declarations in December 2015 on promoting sustainable agricultural commodity supply chains.

6.3.4.4 Urban development

The German government sees towns and cities as key players in endeavours to achieve a global sustainability agenda. German development cooperation activities promote the drafting and implementation of urban development strategies that incorporate climate change mitigation and resilience to the impacts of climate change in partner countries, for example at national and local level. In total, Germany has provided more than EUR 10 billion (USD 11 billion) for climate action in towns and cities over the past five years through its development cooperation activities. There is a particular focus on establishing climate-friendly infrastructure that can withstand climate change impacts. For example, BMZ is supporting the city of Khulna in Bangladesh in adapting to climate change by installing drainage systems in streets and drainage channels. This means that urban areas are no longer flooded for weeks, and the slums benefit in particular because the improved roads give them a permanent connection to the transport system. In addition to the improved flood protection, this presents new economic opportunities for the population. Another example of the establishment of climate-friendly infrastructure in towns and cities is the EcoCasa Project in Mexico; the project will build more than 38,000 energy-efficient houses and 600 houses that meet the Passivhaus standard by 2020 with around half a billion US dollars in private investment. These "eco-houses" consume on average around 20 % less energy than conventional buildings. This enables EcoCasa to save around one million tonnes of carbon dioxide over the entire life cycle of the houses but, at the same time, it also improves the quality of life of many Mexicans who are now able to enjoy better living conditions.

In the International Climate Initiative (IKI), the topic of sustainable urban development cuts across the mitigation, adaptation and biodiversity funding areas. The supported projects assist partner countries in developing strategies for dealing with the impacts of climate change in towns and cities and in making the economic structure more sustainable and low-emission. The digital transformation of cities in connection with smart city approaches is one of the priority areas in the mitigation funding category. Adaptation projects focus on climate-resilient urban development. Biodiversity projects address, for example, the preservation of ecosystem services and promotion of local recreation opportunities. Global targets and guidance on sustainable urban development have been mainstreamed for the first time through the Habitat III process and the design of the New Urban Agenda (NUA).

Furthermore, Germany provided support through BMBF research projects (Rapid Planning funding measure) totalling EUR 6.1 million (approx. USD 6.7 million) to urban growth centres for planning and managing urban infrastructure and services between 2014 and 2016. To this end, planning methods that can be quickly implemented across sectors are being identified and used in pilot projects in Egypt, Rwanda and Viet Nam.

Cooperation on research and technological development

BMBF's CLIENT funding priority establishes international partnerships to research, develop and implement environment and climate technologies and services. It supports partnerships with Brazil, Russia, India, China, South Africa, Viet Nam and Chile, among other countries (approx. EUR 41.6 million (USD 46 million) in 2013–2016).

6.3.4.5 Examples of projects to reduce greenhouse gases

African Renewable Energy Initiative (AREI)

The German government initiated the African Renewable Energy Initiative (AREI) at the G7 summit in Elmau in 2015 and coordinated a joint donor statement pledging USD 10 billion (EUR 9.04 billion) for renewable energy in Africa at the Paris Climate Change Conference. The initiative aims to install ten gigawatts of additional renewable energy output by 2020 and thus supply sustainable energy to the 625 million people on the African continent who have no access to electricity. It aims to expand power generation capacities, adding a total of 300 gigawatts of renewable energy in Africa by 2030. At the Paris Climate Change Conference, Germany agreed to provide a total of EUR 3 billion to support the AREI by 2020. In 2016, BMZ made new commitments for renewable energy, energy efficiency and power transmission and distribution in Africa amounting to more than EUR 1.2 billion (USD 1.3 billion) through bilateral technical and financial cooperation. These commitments contribute fully to the achievement of the AREI targets.

NAMA Facility

The NAMA Facility was launched in 2012 at the initiative of the German Environment Ministry and the British government. It aims to implement ambitious NAMA projects that contribute to the transformative shift to low-carbon development. In addition to Germany and the British Department for Business, Energy and Industrial Strategy (BEIS), the Danish Ministry of Energy, Utilities and Climate (EFKM) and the EU Commission have also contributed to financing the NAMA Facility since 2015.

NAMA Facility funds will support the implementation of mitigation actions and thus directly contribute to closing the mitigation gap by 2020. NAMAs can serve as building blocks of NDC implementation. Since 2013 there have been four calls for proposals (first call: EUR 69 million (USD 76 million) from BMUB/BEIS, second call: EUR 49 million (USD 54 million) from BMUB/BEIS, third call: EUR 84 million (USD 93 million) from BMUB/BEIS/EFKM/EU Commission, fourth call: EUR 59 million (USD 65 million) from BMUB/BEIS). The projects supported through the NAMA Facility utilise the full range of development cooperation instruments.

Support for the Energising Development Partnership (EnDev)

As lead donor, BMZ supports the Energising Development Partnership (EnDev) with the aim of eliminating global energy poverty (SDG 7). EnDev makes a concrete, measurable contribution to the global Sustainable Development Goals (SDGs) while at the same time strengthening climate-related issues such as increasing the use of renewable energy in rural areas by expanding off-grid technologies, increasing energy efficiency by disseminating efficient and climate-friendly stoves and mobilising the private sector to invest in local climate action. In addition, by avoiding deforestation, the project makes a significant contribution to reducing emissions and strengthens the resilience of vulnerable communities and households by creating energy access and promoting local value chains. Since 2005, EnDev has helped 17.3 million people, 38,600 small and medium-sized enterprises (SMEs) and 19,400 social institutions obtain sustainable access to electricity or modern cooking and heating technologies. In addition, EnDev has provided basic and further training to more than 40,000 people in the energy sector, who now contribute to sustainability in the sector. EnDev measures will help avoid the emission of more than 1.8 million tonnes of CO₂ per year as well as additional gases and soot particles that damage the climate and the environment. In total, BMZ supported EnDev with approx. EUR 33 million (USD 37 million) from 2013 to 2016.

Commercialisation of solar energy in urban and industrial areas in India (ComSolar)

Through its International Climate Initiative (IKI), Germany is supporting India in the implementation of its Nationally Determined Contributions (NDCs) and its National Action Plan on Climate Change (NAPCC), adopted in 2008. The ComSolar project has been supporting the Indian partner since 2009 in the development and demonstration of innovative business models for the commercialisation of solar energy in urban areas and the industrial sector. This makes a contribution to implementing the National Solar Mission (installation of 100 gigawatts of solar energy by 2020) and India's NDCs. Measures include feasibility studies, technology transfer, information campaigns and comprehensive capacity building of the partners.

Supporting worldwide emission reduction measures in the transport sector

TRANSfer III supports global projects in partner countries in developing mitigation actions in the transport sector until they are ready for implementation. Among other things, it provides advice on efficiency in goods transport in Indonesia and Peru and urban transport in the Philippines. The aim of the project is for emerging economies and developing countries to strengthen their commitment to climate-friendly transport, supported by the international community.

TRANSfer supports the development of mitigation measures in transport through multi-donor initiatives, such as the Mobilise Your City Initiative (see section 6.3.4.2 above). Events such as the annual Transport and Climate Change Week in Berlin promote South–South exchange. Tailored knowledge products and participation in international networks, such as the Partnership on Sustainable Low Carbon Transport, make it possible to utilise the experience of third parties and provide incentives to step up climate action in the transport sector.

Mitigation and adaptation to the impacts of climate change in agriculture

As part of its work within the FAO's Mitigation of Climate Change in Agriculture (MICCA) initiative, the Federal Ministry of Food and Agriculture (BMEL) developed a database for monitoring and assessing greenhouse gas emissions and their mitigation potential in the agricultural sector. To that end, a system was set up in FAO member states to identify and assess greenhouse gas emissions and possible mitigation strategies and pass on the information to a central database. It will ultimately extend to supporting the countries in building capacities to minimise the damage and risks of climate change. It enables member states to identify and assess greenhouse gas emissions and possible reduction strategies and include them in their national reports.

BMZ supports the International Fund for Agricultural Development (IFAD) in mobilising resources to support smallholders and landless farm workers. BMZ provided EUR 13 million (approx. USD 14 million) for the IFAD climate change adaptation programme for smallholders. Through its investment projects in partner countries, IFAD promotes measures on climate change adaptation for smallholders and on the avoidance of greenhouse gas emissions from agriculture.

6.3.5 Methods, assumptions, REDD+ approaches and important initiatives with German involvement

Reducing emissions from deforestation and forest degradation and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries (REDD+) is a cornerstone of Germany's international cooperation and

development cooperation in the forestry sector. Germany (BMZ and BMUB) provided over EUR 1 billion for financing REDD+ in the period 2008–2016. The share of the ongoing bilateral and multilateral REDD+ portfolio (EUR 751.1 million (USD 830.9 million)) in the ongoing total portfolio (approx. EUR 1,650.7 million (USD 1.826 billion)) is 45.5 %, and has increased by 31 % in comparison to 2015 (EUR 574.5 million (USD 635.5 million)). If the new REDD+ commitments from 2016 are included, REDD+ receives nearly 49 % of BMZ's total bilateral and multilateral forestry portfolio. Germany's development cooperation supports relevant forest countries in creating an enabling environment for implementation of REDD+ at national and sub-national level (e.g. good governance, participation of civil society and indigenous associations, monitoring of forests). In addition it provides results-based financing for countries that can already demonstrate avoided deforestation. This occurs through bilateral and multilateral support programmes.

Germany is taking part in a joint initiative with Norway and the United Kingdom in order to make further progress in protecting forests (Germany, Norway, United Kingdom (GNU)). The aim is to promote the REDD+ approach more broadly, implement integrated land-use programmes and strengthen private sector investment in deforestation-free value chains. The German government views this initiative as part of the implementation of the New York Forest Declaration that was signed in September 2014.

GNU already achieved its goal of providing financing for 20 new REDD+ programmes by the end of 2016 in the first half of that year. In addition, GNU plans to strengthen the structural preparations for REDD+ in over 50 countries over and above all ongoing programmes and initiatives, and also to support the comprehensive financing of REDD+ programmes through the Green Climate Fund (GCF). In concrete terms, Germany and Norway pledged EUR 45.2 million (USD 50 million) from the REDD+ Early Movers (REM) Programme (see below) to the government of Ecuador for reducing emissions through avoided deforestation. Colombia is also supported by the REM programme and received approx. EUR 113 million (USD 125 million) from the trilateral donor community, of which the German government has contributed approximately EUR 30.5. An additional EUR 25 million (USD 27.7 million) was pledged at the end of 2016 for a REM programme in Mexico.

During the Paris Climate Change Conference in December 2015, the governments of the United Kingdom, Norway and Germany announced that they would provide EUR 6.1 billion (USD 5 billion) for the period 2015–2020, or EUR 0.904 (USD 1 billion) annually until 2020 for REDD+. There is a requirement that the partner countries submit high-quality programmes to reduce emissions and demonstrate verifiable political will to reduce deforestation.

BMZ launched the REM programme back in 2012 in order to support forerunners in forest conservation for climate change mitigation and to test results-based REDD+ finance. REM provides compensatory payments for verified emission reductions and focused support for the components still missing in the REDD+ system. At least 50 % of the payments made to the Early Mover partner countries benefit the forest users, many of whom are indigenous population groups. BMZ has provided funding amounting to EUR 59.5 million (USD 65.8 million) up to now. It disbursed EUR 16 million (USD 17.7 million) in Acre, Brazil and EUR 6.45 million (USD 7.1 million) in Colombia by the end of 2016. The implementation of the Ecuadorian country component is currently underway, and other country components are being tested in Latin America and Asia. BMUB supported the Acre, Brazil country component with an additional EUR 9 million (approx. USD 10 million). The GNU partners Norway and the United Kingdom have provided an additional EUR 115 million (USD 127.2 million) for results-based financing.

The measures financed by the German government aim not only at reducing emissions but also at improving adaptation to the impacts of climate change. The rehabilitation of mangrove forests in South-East Asia and forests in water protection areas as well as measures to protect against erosion in areas in Sub-Saharan Africa affected by advancing desertification are examples of projects that can minimise the consequences of global climate change on the local population.

The Bonn Challenge is an essential German development cooperation tool for conserving natural resources. The initiative was founded based on a ministerial conference of the same name that BMUB organised in 2011 in Bonn in conjunction with the International Union for Conservation of Nature (IUCN). It calls for 150 million hectares of forest to be restored by 2020, or the required processes to have at least been initiated. The German government is supporting the implementation through local initiatives and pilot projects as part of its International Climate Initiative (IKI). It is strengthening capacities in the countries and developing the analytical groundwork and maps to identify the potential to rehabilitate forests.

BMZ has been supporting the Amazon Forest Conservation and Climate Fund since 2008, which is the first national REDD+ financial mechanism in Brazil or anywhere in the world, with a total of EUR 21 million in financial cooperation (approximately USD 23 million) and EUR 4.2 million (USD 4.6 million) in technical cooperation. At the Brazilian-German–intergovernmental consultations in Brasilia, Chancellor Merkel raised the prospect of providing a further EUR 100 million (USD 111 million) in financial cooperation.

6.3.6 Report on strategies and measures that promote the mobilisation of private investment in climate change mitigation and adaptation measures in developing countries

Strategies and measures that help make financial flows consistent with climate-friendly development as set out in Article 2.1.c of the Paris Agreement ("shifting the trillions") and that contribute to mobilising private investment in climate change mitigation and adaptation are fundamental building blocks of German climate finance.

Achieving this requires clear price signals and a reliable, long-term enabling environment. The aim is to deploy the limited public funds so that they effectively mobilise private funds (both through financial and technical cooperation) for climate change mitigation and adaptation with the highest possible transformative impacts in non-Annex I countries. This involves not only the direct mobilisation effect; it also involves structural changes in the economy and in the financial sector brought about by taking climate change risks into account and integrating them into decision-making processes.

This includes, for example, reforming climate-damaging subsidies and implementing "green" tax reforms. Key aspects are the utilisation of appropriate financial instruments and their inclusion in partner countries' national systems as well as the creation of an enabling environment that facilitates low-emission, climate-resilient investment. Integrating climate, environmental and social aspects into investment and lending decisions is another key area. Partner countries are supported by a broad range of instruments that include both proven approaches and innovative solutions. There are measures in the following areas:

Policy advice

The German government supports advisory services for policy-makers in establishing guidelines and regulations that facilitate private investment. Example:

- *The Egyptian-German Joint Committee for Renewable Energy, Energy Efficiency and Environmental Protection.* The transformation of the energy sector requires an enabling economic and political environment. In the BMZ-supported Egyptian-German Joint Committee, national actors can exchange ideas beyond their areas of expertise, for example on enabling environments or grid integration of renewable energy. Based on this, Germany's development cooperation provides support in implementing the Committee's decisions. In this way, the Egyptian regulatory agency introduced a feed-in tariff scheme for wind energy, which facilitates the massive expansion of wind power planned by the government.

Project development and preparation of funding proposals will also support public and private actors in mobilising investment. Example:

- *responsAbility Renewable Energy Holding (raREH).* This investment company identifies new project approaches and actively drives their development in order to mobilise private capital for renewable energy projects in Africa. Furthermore, it provides equity financing at all stages of the project life cycle, and especially during the risk and cost-intensive project development phase, thus assuming early project risks. In this way, it makes projects market-ready and attractive to private investors. The structured funds also offer attractive investment opportunities for other development banks and private investors. BMZ provided the initial capital for the fund amounting to approximately USD 27 million in 2013.

The actual and perceived risks relating to investments in climate change mitigation and adaptation can be overcome through advisory services on policy instruments and innovative financial products and by providing data and information. Examples:

- *Regional Liquidity Support Facility.* Many renewable energy projects proposed by private project developers never get off the ground because investors and banks do not consider the government-owned electric utilities' power purchase contracts to be a sufficiently reliable source of income. The cash collateral that they therefore require to safeguard against short-term delays in payment, among other things, is often so high that they are beyond the means of prospective investors. The Regional Liquidity Support Facility is an innovative approach to minimising risk. It offers a liquidity instrument to hedge against the risk of short-term payment delays. BMZ is participating through the KfW Development Bank with EUR 32.9 million (USD 36.4 million). The implementing partner is the African Trade Insurance Agency (ATI), headquartered in Nairobi.
- *Geothermal Development Facility (GDF) for Latin America.* This Facility (a) mitigates geothermal exploration risk; and (b) reduces the capital costs of further development. Qualified project developers receive grants from a risk mitigation fund (BMZ: EUR 35 million (USD 38.7 million); BMUB: EUR 25 million (USD 27.7 million)) to cover the costs of the early exploration phase. If the exploratory drilling is successful, the grant must be paid back and the Facility in turn offers the investors concessional loans to build the geothermal power plant.
- *Global Climate Partnership Fund (GCPF).* The Fund was established with IKI/BMUB and KfW resources and is currently also being supported by the United Kingdom (BEIS) and Denmark (Danish International Development Agency (DANIDA)),, in addition to KfW, a number of other development banks - International Finance Corporation (IFC) (World Bank Group), Development Bank of Austria (OeEB) (Austria), Netherlands Development Finance Company (FMO) (Netherlands) - and

private investors Ärzteversorgung Westfalen-Lippe and the ASN Bank (Netherlands). The total volume amounted to USD 417.2 million (EUR 377.1 million) at the end of 2016, and BMUB was the largest stakeholder with a total of USD 80.7 million (EUR 66.5 million). The GCPF makes innovative and broad-based climate investments, mainly through local financial institutions with a strong focus on renewable energy and energy efficiency. Up to now it has supported 21 partner banks and two direct investments in 17 countries. The Fund is aiming to generate a significant leverage effect, mobilising additional funds from public and private investors (currently USD 80 million (EUR 72.3 million) of private investment in GCPF).

Providing capital to institutions such as local banks for adaptation and mitigation actions and simultaneously building capacities enables them to develop adapted financial products and build a portfolio over the long term. Green finance activities are currently providing almost EUR 2.1 billion to around 120 projects in 20 different countries and nine multi-country approaches. Example:

Eco.business Fund. The structured SME fund has been promoting sustainable private investment by companies and cooperatives in the areas of resource conservation, mitigation and adaptation since 2015. Funds are invested either through local financial intermediaries or directly into projects, and partner banks receive targeted advice on introducing the funding lines. In the first two years it was able to acquire EUR 120 million (USD 108.5 million).

Capacity building

Germany promotes capacity building for various national public and private sector institutions, which is often a fundamental requirement for making private investment possible. Example:

- The German government supports 24 countries with a total of EUR 60 million through bilateral and multilateral channels, including through two readiness programmes in access resources, mainly from the Green Climate Fund (GCF), in a targeted manner. In this way it promotes the results-oriented, transformative and efficient use and implementation of international climate finance. The programmes strengthen beneficiary countries so that they can effectively and efficiently plan to deploy the GCF finance and then utilise it successfully.
- Private Sector Adaptation to Climate Change (PSACC) is a global project that helps SMEs in the cooperation countries to better estimate climate-related risks and opportunities, and develop adaptation strategies. The PSACC project supports private sector actors in using instruments and strategies with which companies can analyse the effects of climate change on the supply of primary products, availability of energy and water, production and sales of their products and services. It also advises chambers of commerce, business associations and management consultants in using these methods and advises SMEs on how to integrate climate change adaptation into their business strategies. BMZ supports the project with a total of EUR 3.6 million (approx. USD 3.9 million). The project is being piloted in Bangladesh, Costa Rica, Morocco and Rwanda.
- Global Inquiry II - Sustainable Financial System. Through its International Climate Initiative (IKI), the German government is helping build capacity to create sustainable financial systems in Kenya, India, Mexico, Mongolia and Morocco. Central banks, regulators and standard-setting organisations are increasingly prepared to implement political innovations at national level in order to incorporate sustainability

principles into the financial system. The project is supporting these actors in their decision-making processes and as such is helping ensure that international financial flows are consistent with sustainable development and with achieving the Paris target of limiting global warming to a maximum of 2 degrees Celsius.

It promotes close cooperation between the private sector and governments in the field of climate risk management in order to provide actors in affected areas with risk management strategies that safeguard their incomes, food security, employment opportunities and access to loans in times of climate change. Example: InsuResilience (see section 6.3.3 above).

Germany is promoting a range of multi-actor dialogues in order to strengthen and replicate the results of successful practices and facilitate the participation of other donors. They facilitate exchange between actors from the public and private sectors in areas such as making governments' climate strategies accessible to private financiers and project developers. Example:

- GreenInvest, initiated under the Mexican G20 Presidency, serves as a dialogue platform with and for developing countries to mobilise and mainstream green finance. BMZ introduced the dialogue platform again in 2017 under the German G20 Presidency. Its work focuses on the role of the financial sector, financial technologies and foreign direct investments in green and climate-friendly development.

The Deutsche Investitions- und Entwicklungsgesellschaft mbH (DEG) works solely with the private sector. It assumes the risks that commercial banks and investors assume to only a limited extent or do not (or are not able to) assume at all. In this way, DEG facilitates the delivery of a suitable financial package in which private investors and commercial banks can take part. Example:

- *Mobisol*. Since 2012 DEG has been working with the German start-up Mobisol, which offers solar home systems in Africa. Initial support, provided through the BMZ-financed develoPPP.de project, facilitated prefinancing for 2,000 units. This was followed by three loans and one equity stake. Two hundred thousand people in rural East Africa were already using the network-independent solar power installations by the end of 2016.
- *SOWITEC*. DEG has been a financing partner of a leading developer of wind and solar projects in Latin America since 2011: the German company SOWITEC. Together with DEG, SOWITEC is developing nine wind farms in Argentina, Brazil, Chile, Colombia, Mexico, Peru and Uruguay with a total capacity of up to 1 gigawatt.

6.4 Technology development and transfer

Technology transfer is a component in virtually all of the German government's climate-related bilateral cooperation. Environmentally friendly technologies, for example in the field of energy infrastructure, are an essential part of economic development and climate action. It is therefore not possible to separately report climate finance contributions that are solely categorised as technology transfer.

There are starting points for technology cooperation at all levels at which German development cooperation operates: at the macro, meso and micro-level. Whereas at the macro level, technology can, for example, promote the design of funding instruments at policy level or the development of sector-specific strategies, these can be fleshed out and tested at the meso-level, for example in capacity building, the establishment of networks

and platforms, and development of technical standards, etc. Investments are financed at micro level, for example in renewable energy generation projects that reduce emissions and replace outdated technologies. Another example of such approaches to technology cooperation at micro-level are development partnerships, through which German companies are supported in cooperating with companies from the partner country on specific projects.

With regard to climate technology, low-carbon energy, climate-smart cities and resilient rural development are areas of particular relevance to German development cooperation.

Germany is involved in technology cooperation through its committed support to the UNFCCC Technology Mechanism and its organisations:

- Technology Executive Committee (TEC) and
- Climate Technology Centre and Network (CTCN).

Germany has been supporting the TEC with voluntary contributions amounting to EUR 550,000 (approx. USD 608,407) and the CTCN with EUR 1,047,019 (USD 1,158,207) since 2013. In 2016 the Federal Ministry of Economic Affairs and Energy (BMWi) set up Germany's National Designated Entity (NDE) office, which serves as a central point of contact for inquiries from the CTCN, other national contact points and German industry. This makes it easier for applicants in partner countries to access German technology. Furthermore, it will support German technology providers in their planned partnerships with organisations in partner countries in order to foster a link between supply and demand.

- German Climate Technology Initiative (DKTI)

Through the DKTI, BMZ is financing modern, climate-friendly and climate-adapted infrastructure measures in emerging economies and developing countries, which reduce GHG emissions and promote adaptation to climate change. It aims to support partner countries in fulfilling their NDCs, establishing the required frameworks and developing sustainable markets. Cooperation with the financial sector facilitates the mobilisation of private investments. There is a particular focus on the following technology fields: renewable energy, the integration of renewable energy and grid expansion, energy efficiency in industry and buildings, waste management, climate-friendly mobility, water supply and irrigation, adaptation technologies, forest conservation and reforestation, and coastal and marine protection. By 2016, projects totalling EUR 7.86 billion (USD 8.7 billion) had been approved.

The EU Energy Initiative Partnership Dialogue Facility (EUEI PDF) is a multi-donor facility aiming to promote renewable energy to achieve equitable and climate-friendly development worldwide. Here the focus is on larger-scale renewable energy.

- In hosting the secretariat of the Africa-EU Energy Partnership (AEEP), the Facility promotes high-level political dialogue between the two continents. Increased attention will be paid to establishing networks between energy and climate actors in order to forge a cross-sectoral alliance for achieving development and climate goals.
- The Africa-EU Renewable Energy Cooperation Programme (RECP) supports companies in developing bankable projects and in so doing contributes to closing the gaps between available climate funds and the numerous, but not always convincing, project approaches. The programme currently supports 25 projects with a capacity of 221 megawatts. The RECP promotes knowledge exchange between the European and African private sector, for example through matchmaking events, from which

joint ventures may emerge. In addition the programme actively promotes European-African Research Partnerships. For example, there is close cooperation with associations and companies through the RECP that aims to pool local interests and represent them. The AEEP's high-level stakeholder forum is a platform for African-European exchange among representatives from politics, civil society, the academic and scientific community and industry. By providing basic finance of approx. USD 5.19 million, BMZ leveraged cofinancing of approximately USD 28 million (other donors: European Commission, Netherlands, Austria, Finland, Sweden).

Transport sector

Germany is known for sustainable solutions and innovative concepts along the entire mobility and logistics chain. German actors look back over a history of continuous transformation towards increased sustainability. This process is far from over and is receiving fresh impetus through the newly founded think tank Agora Verkehrswende, for example. In this context, the German Partnership for Sustainable Mobility (GPSM) has also acted as a 'pilot' and has been the key contact partner for sustainable mobility and logistics solutions from Germany since 2014. The professional network involving industry, academia and civil society promotes dialogue on sustainable transport with actors from developing countries and emerging economies and processes Germany's lessons learned, tailoring them for specific target groups.

Technical cooperation advisory services will help climate-friendly mobility options to gain a firm foothold in the market, for example in the field of electric mobility and alternative fuels, and increase the ability of subnational actors to plan and introduce climate-friendly technologies in the transport sector. An example of this is the C40 Cities Finance Facility that supports the establishment of an electric bus corridor in Mexico City.

Private sector cooperation

Industry plays a key role in designing future-oriented and modern energy supply systems in our partner countries: as a technology supplier and source of finance, but also as a partner that can ensure sustainability. This is because the private sector will engage further where there is business, even after development cooperation activities cease. Many German development cooperation projects therefore aim to create a better technical and policy framework in the partner countries in order to ultimately recruit the support of the private sector as a key actor in the broad-based marketing of appropriate technologies.

Linking up technical and economic expertise and the investment capacities of international and German companies with development aims and thus with technology and knowledge transfer serves to promote multi-stakeholder dialogue and networks (cooperation with associations, development cooperation scouts, specialists in chambers of commerce abroad, energy partnerships).

- development partnerships with the private sector (export initiatives, project development programmes, programmes to promote technology) and measures to promote market development and cofinancing.

Example:

- develoPPP Programme

Through its develoPPP.de programme, BMZ promotes the involvement of the private sector in cases where business opportunities concur with development policy needs. Companies that invest in developing countries and emerging economies receive financial and, if they request it, technical support. Over 1,500 development partnerships have been initiated

since 1999 in all areas ranging from wastewater management to certification. BMZ supported projects with around EUR 130 million between 2013 and 2016. Some of these were considered climate-related because they involved investment in renewable energy, energy efficiency, biodiversity and forestry.

6.5 Capacity building

Capacity building is an integral part and core element of virtually all the German government's bilateral cooperation projects. It is therefore not possible to separately report finance streams used exclusively for capacity building.

The German government is involved in capacity building through bilateral and multilateral cooperation as well as various partnerships with the private sector, academia and civil society. In order to support partner countries in the effective implementation of the United Nations Framework Convention on Climate Change and the Paris Agreement, it provides comprehensive measures on capacity building in the areas of greenhouse gas reduction, adaptation to climate change, technology development and transfer, and access to climate finance, as well as other specific sectors and cross-cutting aspects such as reporting (see sections 2, 3, 4, 6 and CTF Table 9). In implementing these measures, the government takes guidance both from the decisions of the Parties to the United Nations Framework Convention on Climate Change and from the principles of the agenda to increase the effectiveness of development cooperation that is part of the Paris-Accra-Busan process, which include ownership by the partner countries, using the partner institutions and procedures, coordination among donors, results orientation and mutual accountability on the part of partners and donors. The support measures for capacity building are designed to be context-specific, results-based and consistent with national priorities,. The German government's activities also aim to bring the development goals set out in Agenda 2030 and the climate agenda closer together.

In this work, it uses its range of international cooperation instruments and institutions to build capacities at individual, institutional and systemic level in the area of climate and development:

- Bilateral financial and technical cooperation (e.g. KfW Development Bank, DEG, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the German Federal Institute for Geosciences and Natural Resources (BGR);
- Multilateral cooperation, such as multilateral development banks and United Nations organisations, the European Union, the Global Environment Facility, including the Capacity Building Initiative for Transparency (CBIT), the Forest Carbon Partnership Facility, the Climate Investment Funds and the Adaptation Fund under the Kyoto Protocol;
- Private sector partnerships, such as the climate risk insurance initiative InsuResilience, develoPPP/development partnerships;
- Cooperation with civil society such as non-governmental organisations, political foundations, churches;
- Cooperation with scientific institutions such as the Potsdam Institute for Climate Impact Research (PIK) and the World Resources Institute.

See sections 6.3.3 and 6.3.4 of this report as well as CTF Table 9 in the Biennial Report for an example of capacity-related measures and initiatives in the areas of greenhouse gas reduction and climate change adaptation, and at sector level.

Competence centres for climate change and adapted land use in Africa

Together with partners from ten West African countries and five Southern African countries, the Federal Ministry of Education and Research (BMBF) is building two regional competence centres for climate change and sustainable land management (Regional Science Service Centres, RSSCs) in Western and Southern Africa, so that the countries themselves can take valid decisions, for example with regard to their land use and water supplies. Programmes to nurture young scientists and build research capacities in these countries play a key role here (approximately EUR 71.8 million (USD 79.4 million) in 2013–2016).

Building competencies is also an essential component in BMBF's research programme entitled Science Partnerships for the Assessment of Complex Earth System Processes (SPACES). Academics from German universities and non-university research institutions are working with partner institutions and universities in the Southern African priority countries Namibia and South Africa in academic cooperation projects. The programme helps to draft science-based recommendations on managing the Earth's systems and to ensure the sustainable use and conservation of ecosystem services in the region. In addition to the summer schools and workshops carried out alongside the project, BMBF initiated a supplementary study programme in conjunction with the German Academic Exchange Service (DAAD). This programme aims to provide training and continuing professional development to African university students and young researchers with a focus on environmental sciences, landscape ecology, geology and oceanography.

7 Vulnerability, impact of climate change and adaptation measures

7.1 Adaptation policy in Germany: German Strategy for Adaptation to Climate Change (DAS)

Climatic changes have an impact on nature and the environment. Climate change and the required adaptations to its effects pose a major political challenge for the 21st century. Timely adaptation is also becoming increasingly important for Germany if it is to limit damage and risks from changes in the climate and avoid incurring higher costs associated with damage and adaptation at a later date.

7.1.1 Development and coordination of DAS efforts

In order to combat these challenges, the federal cabinet, with the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) serving as lead agency, agreed on the German Strategy for Adaptation to Climate Change (DAS) in December 2008. The overarching aim of the DAS is to identify and reduce Germany's vulnerability to climate change impacts and increase its climate change adaptation capacity, thus ensuring that existing operational objectives in the different policy areas remain as achievable as possible, even in conditions resulting from advancing climate change. The Strategy is divided into 15 fields of action in the following areas: building, biodiversity, soil, the energy industry, the finance and insurance industry, fisheries, forestry, trade and industry, agriculture, human health, tourism, transport and transport infrastructure, water, flooding and coastal protection, and spatial, regional and physical development planning, and civil protection and disaster control.

In order to flesh out the DAS, the federal cabinet subsequently approved an initial Adaptation Action Plan (APA I) on 31 August 2011.¹⁸³ APA I underpins the DAS with specific federal government activities and identifies links with other national strategy processes. The first DAS progress report and an Action Plan II were adopted by the German government¹⁸⁴ in December 2015. The progress report led to a regular reporting cycle being agreed with the following deliverables: monitoring report every 4 years (2019), vulnerability analysis every 5–7 years (2021), evaluation report (2019), and progress reports and action plans every 5 years (2020).

The supervision and interministerial coordination of DAS efforts is carried out through the federal government's Interministerial Working Group on Adaptation Strategy with BMUB as lead agency. Furthermore, the Conference of Federal and Länder Environment Ministers (UMK) set up a Permanent Committee on Adaptation to the Consequences of Climate Change (StA AFK), which is part of the Joint Working Party of the Federal Government and the Länder on Climate, Energy, Mobility - Sustainability (BLAG KliNa). The Länder also take part in the progress report work through the StA AFK.

Key DAS products and updates are adopted through federal cabinet decisions.

BMUB created a Competence Centre on Climate Impacts and Adaptation (KomPass) at the Federal Environment Agency to help design and further develop a national strategy for

¹⁸³ German government (2011).

¹⁸⁴ German government (2015).

adapting to climate changes. KomPass provided the technical-strategic groundwork for drafting and updating the DAS. KomPass is an information platform for specialised expertise on climate change impacts and adaptation and for Germany's adaptation activities.

7.1.2 2015 DAS progress report

A first milestone in the implementation of the German Strategy for Adaptation to Climate Change (DAS) was the Adaptation Action Plan adopted by the federal cabinet in 2011. In December 2015, the federal government presented the first DAS progress report,¹⁸⁵ which takes stock and describes the status of activities. The progress report provides a summary overview of developments with regard to the analysis of observed and projected climate changes. The core APA I projects that have already been implemented are the establishment of a monitoring system with indicators for the observed impacts of climate change and completed adaptations and the development of a standardised methodology for determining vulnerability. The DAS monitoring report published in May 2015 presents, for the first time in compact form using measured data, the climate changes that have already been detected in Germany.¹⁸⁶ Germany's first consistent, comprehensive vulnerability analysis, which was prepared using standardised methodology, was submitted in November 2015; it identifies the regions and systems that are particularly affected by climate change across all fields of action.

Based on an assessment of these comprehensive research activities, an evaluation of previous support programmes and measures and the results of the vulnerability analysis, the progress report draws conclusions regarding the government's priority actions and its other associated activities and measures for the coming years. A comprehensive package of federal government measures, the Action Plan II (APA II), is included in the progress report as an Annex.

The second Adaptation Action Plan (APA II) was published as part of the 2015 progress report. The APA II comprises measures that are specific to fields of action or sectors as well as those that are of fundamental importance for all/many fields of action. In many ways, the latter serve to make available to planners and decision-makers the country-wide, standardised groundwork for action needed over the long term. In this way, APA II marks the transition from one phase of primarily project-based, fixed-term measures to a phase in which designated tasks are established on a longer-term basis. This also partly applies to measures that are specific to fields of action or sectors and are intended to become part of the administrative operations of federal agencies in future. The measures presented in the progress report and APA II are the responsibility of the specific ministries and – subject to available budgetary resources – are earmarked for financing through the respective budgetary and financial planning strategies in effect (including human resources in those ministries).

The federal government began to establish a comprehensive portfolio of climate services and climate change adaptation services at the end of 2015 to support the implementation of DAS; their main task is to deliver the required climate services reliably over the long term.

¹⁸⁵ See German government (2015).

¹⁸⁶ Federal Environment Agency (2015a).

7.1.3 Further development of DAS

Whereas Germany devoted the last 10–15 years to strategy development and the closing of knowledge gaps as its top priority, the focus of work has now shifted to user level. The first tools and instruments were developed through pre-competitive applied research. These depict climate change impacts at regional and local level in a more robust way for planners and decision-makers and must now be gradually operationalised and consolidated. Moreover, implementation up to now focused on systematically incorporating the task of climate change adaptation into existing information, legal and economic instruments. This mainstreaming process will continue. In parallel, the tools practitioners need must be developed based on methodologies and data standardised across Germany and then integrated into the existing planning and operational procedures to ensure adequate and timely responses to the impacts of climate change. This helps put societal actors in a position to respond with flexibility to the risks of climate change - either on their own or supported by governmental institutions.

As set out in the 2015 progress report, the DAS process should be consolidated as follows. The implementation of the DAS process must be mainstreamed at operational level and made into a permanent routine operation. To this end, access to the existing scientifically accepted knowledge and data must be assured on a permanent basis. This enables the impacts of climate change to be comprehensively taken into account in all planning over the long term. All of the federal government's consolidation activities support Länder activities. The Länder therefore expressly support initiatives such as Germany's vulnerability analysis, the concept of a future federal government portfolio of climate services and climate change adaptation services and regular monitoring reports.

The main features of the ongoing DAS process is that it makes available, updates and further develops the required prediction and projection data and other regular services on a continual basis. In particular, this gives the sectoral agencies relevant to government that deal with climate and climate change adaptation a new permanent responsibility. This applies primarily to the areas of water and extreme weather, where the responsible specialised federal agencies are further developing their existing long-term operational portfolios with the aim of making them available to the central climate services.

The restructuring of responsibilities increases the importance of a coordinated federal approach. The format of an interministerial working group that coordinates the climate adaptation process at federal level has proven successful. This also applies to the Federal/Länder Committee under BLAG KliNA - the Permanent Committee on Adaptation to the Consequences of Climate Change (Sta AFK) - and to supporting organisational forms such as the Federal/Länder expert discussions on climate change impacts or the interpretation of regional climate model data.

The German government is planning to set up a comprehensive portfolio of climate services and climate change adaptation services. To this end it has developed a two-pillar approach that comprises a German Climate Service (Deutscher Klimadienst, DKD) and a portfolio of climate change adaptation services (KlimAdapt). Furthermore, the government will fulfil its steering function with the help of other frameworks set by informal, economic and legal instruments. The informal instruments seek to establish information, cooperation and participation measures involving governmental and non-governmental actors. In future, the focus here will be on measures that improve information on the impacts of climate change both region-specific and over time and the tailor-made options for action. Formal instruments of a binding nature will speed up the implementation of adaptation to climate

change, for example with a view to making necessary distinctions in the specifications of regional development plans and programmes. In future, the government will increasingly use legal frameworks such as primary and secondary legislation or technical regulations and standards to mainstream climate change adaptation issues. Economic instruments hold great potential for promoting climate change adaptation and there are plans to make greater use of that potential in future.

The most important APA II activities are:

Spatial planning and civil protection. Tackling climate change, including its regional manifestations, remains a long-term and dynamic challenge in spatial planning. This will be taken into account in the further development of the Principles and Action Strategies for Spatial Development in Germany drafted by the Standing Conference of Ministers Responsible for Spatial Planning (MKRO).

Activities under the APA II, such as the Climate-Change-Sensitive Regional Plan research project, the KlimaMORO transfer of results into broader practice, and Climate-Resilient Urban Restructuring, build on experience gained through the federal government's APA I model projects.

Another priority of federal government activities is the further development of planning instruments to facilitate better integration of climate change adaptation requirements into planning processes. This objective led to the establishment of the Climate-Change-Sensitive Regional Plan (Klimawandelgerechter Regionalplan) project, which aims to integrate risk and hazard maps into spatial planning and assess opportunities to make spatial and land-use planning goals more flexible.

An overarching activity that connects civil protection and spatial planning is the continuation of the Strategic Agencies' Alliance for Adaptation to Climate Change (in place since 2007), consisting of the Federal Office of Civil Protection and Disaster Assistance (BBK), the Federal Environment Agency (UBA), the Federal Agency for Technical Relief (Technisches Hilfswerk) (THW), the Deutscher Wetterdienst (German Meteorological Service, DWD) and the Federal Institute for Research on Building, Urban Affairs and Spatial Development (BBSR). There is another partnership with the German Committee for Disaster Reduction (DKKV), whose members include a broad range of governmental institutions, research institutions, industry, non-governmental organisations and independent experts.

Water regime, water management. One measure to improve information and data resources is the DAS field of action on the general provision of data and advisory services on water resources. It will deal with historical data, current data from ongoing measuring networks and future-oriented projection data that will be generated. An integral component of flood risk management and a key instrument to improve flood protection in Germany is the National Flood Protection Programme (Nationales Hochwasserschutzprogramm) (NHWSP) in conjunction with the Measures for Preventative Flood Protection (Massnahmen des präventiven Hochwasserschutzes) special framework plan (SRP) of the Federal Government/Länder Joint Task for the Improvement of Agricultural Structures and Coastal Protection (GAK). Furthermore, the federal government plans to work with the Länder to revise other material flood defence regulations in order to improve preventative protection. The Development of Risk and Hazard Maps for Heavy Rains and Flash Floods (Erstellung von Risiko- und Gefahrenkarten für Starkregen und Sturzfluten) instrument was assessed for its potential to improve the handling of floods and the impact of heavy rain events on sewage networks and treatment plants. Work is being done to introduce a formal

planning module for determining and assessing climate change impacts in management plans and the Water Framework Directive in order to adequately take into account the impacts of climate change on the status of water bodies.

Coastal and marine protection. A range of measures will be carried out in this field of action that relate to monitoring and provision of data on water levels and to the physical and chemical status of water bodies. The Federal Government/Länder Joint Task for the Improvement of Agricultural Structure and Coastal Protection (GAK) serves as the framework for collaboration on coastal protection between the federal government and the Länder. In response to the dangers of climate change, the GAK special framework plan entitled Coastal Protection Measures in Response to Climate Change (Massnahmen des Küstenschutzes in Folge des Klimawandels) was developed for 2009–2025.

The building sector. There is a focus on the impacts of heat and thus on the adverse effects on the urban climate, and on challenges for temperature regulation in buildings. The extent to which the Federal/Länder Social City Support Programme (Bund-Länder-Förderprogramm "Soziale Stadt") is suitable for combating heat island effects and the associated health risks will be assessed. A revision of the efficiency standards in the Energy Conservation Regulation (EnEV) is being considered in order to counteract the increased energy consumption for cooling buildings.

The possibility of making adaptations to the building regulations to address future climate risks, the revision of climate data standards and technical regulations and standards relating to include climate change impacts, and the development of a geographical information system to facilitate country-wide risk assessment of future climate impacts on buildings are relevant to a broader range of climate change impacts. In its own area of responsibility, the federal government is planning for the systematic inclusion of climate change adaptation aspects in the refurbishment of existing federal government properties and construction of new ones.

Energy industry. With regard to the scarcity of cooling water for thermal power plants, thermal load plans will be assessed with respect to changed hydrological and temperature conditions, which will provide impetus for necessary adaptations.

Transport, transport infrastructure. Recording vulnerability and evaluating the adaptation of technical regulations that apply to Deutsche Bah AG infrastructure contributes to the adaptation of railway infrastructure. The identification of alternative train routes is particularly aimed at responding to flood events.

The Adaptation of Road Infrastructure to Climate Change (AdSVIS) programme analyses the impacts of climate change on road transport infrastructure and road maintenance, carries out vulnerability assessments for individual infrastructure elements and develops and tests adaptation options and technologies. The research results relating to climate change are to be fed into the policies of the corresponding committees that develop codes of practice.

An overarching federal government activity relating to waterways and shipping is establishing adaptation to climate change in the administrative structure and portfolio of activities of the Federal Waterways and Shipping Administration (WSV) as a new permanent task. A major focus for inland waterways is the trend in low water situations.

In order to better handle the complex technical requirements and challenges for future topics such as climate, the German Ministry of Transport and Digital Infrastructure (BMVI) established in 2014 an expert network involving its sectoral research facilities, which works

across different modes of transport in order to harness synergies to achieve the required scientific progress and provide decision-makers with a new quality of advice.

Soil There have been country-wide data and maps on the threat of soil erosion from wind and water since 2014; they are now to be updated and validated as part of APA II. One of the focuses of soil conservation activities is protection of bogs, which are valuable not only as water reservoirs and biotopes but also act as carbon sinks, and thus play an important role in climate change mitigation.

Biodiversity. The spread of invasive species is a specific challenge with a specific need for action. To address this and other problems, opportunities for a coordinated federal and Länder approach to establish a system to monitor the direct and indirect impacts of climate change on biodiversity in Germany are to be assessed. A comprehensive range of activities is planned for sites that are important for species, ecosystem services and biotopes and habitats, including continuing and strengthening research on biodiversity and climate change and continuing support for measures to secure adaptive capacity to climate change as part of the Federal Biological Diversity Programme.

Integrated spatial planning principles to facilitate adaptable and robust spatial and landscape structures are to be developed for legal and planning instruments in the field of nature conservation.

Agriculture. The federal government is planning several research activities that primarily deal with the impacts of pesticides under conditions brought about by climate change.

Forestry. The Forest Climate Fund (Waldklimafonds) makes it possible to implement measures that tap into and optimise the CO₂ mitigation, energy and substitution potential of forests and wood and help adapt German forests to climate change. The fund's resources can help, for example, restore and plant new natural or environmentally managed riparian and moist forests and make them more dynamic. In addition to private forest owners, the government as a forest owner itself also plays an important role in implementing adaptation measures. This aspect is taken into account with the Development of Federally Owned Climate Adaptive Forests (Schaffung klimaplastischer Wälder im Eigentum des Bundes) measure.

Health. One focus of the activities is on measures to monitor the spread of disease vectors in connection with relevant climate signals. The monitoring focuses on infectious vector-borne diseases and on sensitisation to allergens (e.g. pollen and mould). Furthermore, the federal government is assessing activities to expand and reinforce health and environmental monitoring and to develop an integrated health and environmental monitoring system.

In order to address the extreme heat caused by climate change particularly effectively, the government is looking into developing heat action plans in accordance with World Health Organization (WHO) recommendations.

A baseline study and a central information platform in the field of climate change and health was created during the country-wide survey of adaptation activities in 2014. This is the first ever compilation of federal-level and Länder-level adaptation activities relating to climate change and health. The information platform enables all actors to network more effectively with each other at the various levels and learn from one another.

Industry and trade Technical Rules on Plant Safety (TRAS) (Technische Regel Anlagensicherheit) were prepared for the potential hazards of wind and snow. They take

into account the probabilities and intensities of extreme wind events, such as storm gusts and tornadoes, which could be influenced by climate change.

Finance industry The APA II activities mainly relate to raising awareness among actors, exchanging experience and improving available data resources. Furthermore, international provisions require that financial services companies include basic data and factors relating to climate and extreme weather in their risk considerations.

7.1.4 Comprehensive range of federal climate change and adaptation services

The German government is establishing a comprehensive portfolio of services addressing climate change and adaptation. In implementing the Global Framework for Climate Services (GFCS) at national level, the government set up the German Climate Service (Deutsche Klimadienst, DKD) in autumn 2015, which has its office at the Deutscher Wetterdienst (German Meteorological Service, DWD). The partners involved in the DKD supply the climate information and services needed to implement the DAS and its associated action plans.

The German Climate Service is to be expanded by a portfolio of climate change adaptation services (KlimAdapt Germany). They will include the observation and assessment of climate change impacts, an analysis of vulnerabilities to identify risks, the development and assessment of climate change adaptation measures and instruments, the establishment of suitable frameworks for developing and enhancing adaptive capacities and the evaluation and implementation of adaptation activities.

Setting up the offices for the German Climate Service (at DWD) and the KlimAdapt adaptation services (at UBA/KomPass) creates organisational structures for designing the tasks and work processes – which are already being carried out today in part through DAS implementation – more efficiently and for establishing them as permanent tasks. The Interministerial Working Group on Adaptation to Climate Change has taken on the role of steering committee for DKD and KlimAdapt and secures the participation of Länder in cross-cutting decisions (e.g. by inviting them to attend as guests).

7.1.5 Länder activities

The Länder have addressed climate change adaptation in many different ways:

- Implementation and assessment of research projects;
- Further development or revision of new political strategies and plans for measures with varying degrees of binding force;
- Initiation and implementation of (pilot) projects;
- Establishment of competence centres;
- Holding regional conferences.

The responsibilities of the federal government and the Länder as well as those of the local administrative levels must be observed in the implementation of climate change adaptation measures. In order to tackle climate challenges, some Länder have set up institutions over the past few years that specifically deal with adaptation to climate change, such as the Competence Centre for Climate Change Impacts in Rhineland-Palatinate (Kompetenzzentrum für Klimawandelfolgen in Rheinland-Pfalz), the Thuringian Climate Agency (Thüringer Klimaagentur) and the Hessian Centre on Climate Change

(Fachzentrum Klimawandel Hessen). The role of the technical and competence centres in the Länder is to address, raise awareness among and advise local policymakers in various sectors and provide them with specific information tailored to each target group to facilitate their decision-making.

An overview of key Länder activities will be provided in the following:

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Brandenburg	-	Sustainability Strategy 2014 Catalogue of adaptation measures from 2008	A monitoring system is being established. There is a basic indicator report by the State Agency for the Environment (Landesamt für Umwelt, LfU) with 38 indicators, and an additional indicator report on sustainability with 49 indicators	-	Interministerial Working Group on adaptation to the impacts of climate change LfU project group on climate change

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Berlin	Berlin Energy Transition Act (EWG Bln) from 22 March 2016	Strategy for Adapting to the Impacts of Climate Change in Berlin (AFOK) 2016	<p>A climate impact monitoring system focusing on Länder and impact indicators has been set up and will undergo continuous development. The first status report was prepared in 2016.</p> <p>Currently, a digital monitoring and information system for the Berlin Energy and Climate Programme (BEK) and the Strategy for Adapting to the Impacts of Climate Change in Berlin (AFOK) is being set up. Expected completion 12/2017.</p>	The Energy Transition Act requires that an energy and climate programme be drawn up that contains strategies and measures for adapting to climate change impacts and that a system to monitor climate impacts be set up	Working groups and expert consultations that cut across sectors and agencies

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Baden-Württemberg	Climate Change Act (Klimaschutzgesetz) (KSG BW) (2013)	Strategy for Adaptation to Climate Change in Baden-Württemberg (2015)	Reporting to become mandatory in 2016 (Article 9, Climate Change Act) Adoption of the indicator-based report expected mid-July	State spatial planning act (Landesplanungsgesetz)	Interministerial Working Group on Adaptation

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Bavaria	-	<p>Climate Policy Programme Bavaria 2050 (2015) with a pillar entitled "Regional Adaptation to the Impacts of Climate Change – Making Bavaria Climate-Proof"</p> <p>Bavarian Climate Change Adaptation Strategy (BayKLAS) (2009), update completed at the beginning of 2016; cabinet decision from 13 September 2016</p> <p>Published in November 2016</p>	<p>Climate Adaptation Indicator System study, 2016 to mid-2017</p> <p>(Final report available). Indicator set to describe and assess climate change impacts and adaptation measures</p>	<p>See BayKLAS 2016:</p> <p>Bavarian Water Act (Bayerisches Wassergesetz);</p> <p>Bavarian Agriculture Act (Bayerisches Agrarwirtschaftsgesetz);</p> <p>Bavarian Forest Act (Bayerisches Waldgesetz);</p> <p>Bavarian Nature Conservation Act (Naturschutzgesetz);</p> <p>Bavarian Compensation Regulation (Bayerische Kompensationsverordnung);</p> <p>Bavarian Soil Protection Act (Bayerisches Bodenschutzgesetz);</p> <p>Bavarian Spatial Planning Act (Bayerisches Landesplanungsgesetz).</p>	<p>Climate Change Working Group for State Administrations and National Parks</p> <p>Interministerial Working Group on Climate Change ;</p> <p>Bavarian State Ministry of the Environment and Consumer Protection, Climate Panel</p>

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Bremen	Climate Act (Klimaschutzgesetz) Bremen, March 2015	Adaptation Strategy (in preparation, to be submitted mid-2017)	Bremen has no climate change impact monitoring system at state level; controlling is planned as part of the adaptation strategy	-	Interministerial project group
Hamburg	1998, does not include adaptation	2011, 2013 Climate plan 2015, includes adaptation	The impact indicators were fleshed out and published at the beginning of 2017.	None	Interagency working group with government agencies and public enterprises
Hesse	No; 2017 cabinet decision	Adaptation Strategy (2012); Integrated climate action plan published in March 2017	There is a climate change impact monitoring system with approximately 20 indicators; it is being further developed as part of the implementation of the integrated climate action plan.	State Nature Conservation Act (Landesnaturschutzgesetz) State Spatial Planning Act (Landesplanungsgesetz)	Inter-ministerial Integrated Climate Action Plan Working Group

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Lower Saxony	-	Adaptation Strategy (2012), Climate Policy Implementation Strategy (2013), implementation report (2015)	Monitoring of measures		Interministerial Climate Action Working Group with the Working Group on Adaptation ((for all ministries) Climate Change Competency Network (three posts)
North Rhine-Westphalia	NRW Climate Change Act (2013)	Adaptation Strategy (2009); Climate Action Plan (incl. adaptation) (2015)	There is a climate change impact monitoring system with 23 indicators; more comprehensive monitoring, also for the implementation and impacts of the NRW Climate Action Plan, will be developed based in part on the DAS monitoring report, etc.	State Nature Conservation Act (Landesnaturschutzgesetz) State Spatial Planning Act (Landesplanungsgesetz) State Forest Act State Water Act	Interministerial Climate Action Plan Working Group ; Ministerial Working Group on Adaptation to Climate Change
Mecklenburg-West Pomerania	-	-	-	-	-

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Rhineland-Palatinate	State Climate Change Act (Landesklimaschutzgesetz, LKSG) (2014) – without adaptation	Climate Change Report – principles and recommendations (2013), Climate Change Information System (since 2011)	Indicators/monitoring strategy based on DAS monitoring in preparation	State Climate Change Act (Landesklimaschutzgesetz) (only indirect reference)	Climate Change Advisory Panel Rhineland-Palatinate Interministerial Working Group
Schleswig-Holstein	Schleswig-Holstein's Climate Change Act (Klimaschutzgesetz) has been in deliberations since December 2015; adoption planned for 2016.	Adaptation timetable for 2011 (is currently being revised)	Indicators were defined for the areas of water management/coastal protection, environment/biodiversity, agriculture and forestry in line with DAS indicators in order to facilitate monitoring. A monitoring system is being developed.	State Spatial Planning Act (Landesplanungsgesetz), Climate Change Act (Klimaschutzgesetz), Other targets set in the State Development Strategy (Landesentwicklungsstrategie) and the Landscape Programme (Landschaftsprogramm)	Climate Change Adaptation Working Group at the Ministry of Energy, Agriculture, the Environment, Nature and Digitalization) (MELUND) Halligen Islands Working Group 2050, Lowlands 2050 Working Group (Marsh Association)
Saarland	-	-	-	-	-

Land (state)	Primary legislation on climate action, including adaptation (year)	Adaptation strategy (year)	Monitoring	Primary legislation related to adaptation	Administrative cooperation committees
Saxony	-	Energy and Climate Programme, including a catalogue of measures (2012); Agriculture Adaptation Strategy (2009)	Climate impact monitoring with 26 indicators (as of 2016)	State Development Plan 2013	Working Group on Climate Impacts at the State Ministry of the Environment and Agriculture
Saxony-Anhalt	-	Adaptation Strategy 2010, update in 2013; The ongoing update, target date: mid-2018	Indicators/monitoring strategy in preparation, Preparation of a brochure on climate analysis for Saxony-Anhalt	State Development Act (Landesentwicklungsgesetz) 2015	Climate change working group that cuts across sectors and ministries
Thuringia	Planned for 2017	Integrated Programme of Measures to Adapt to the Impacts of Climate Change in the Free State of Thuringia (IMPAKT 2013) (Update 2018)	Monitoring report 2017	State Development Plan 2025	Thuringia Climate Agency; Interministerial Working Group on Climate Change Impacts and Adaptation Regional Climate Information System (ReKIS) – Saxony, Saxony-Anhalt, Thuringia

Table 22: Overview of Länder (state) climate change adaptation activities¹⁸⁷

¹⁸⁷ Source: Permanent Committee on Adaptation to the Consequences of Climate Change of the Federal-Länder Working Group on Climate and Sustainability (Bund-Länder-Arbeitsgruppe Klima und Nachhaltigkeit), as of: July 2017.

7.1.6 Cross-evaluation of collaborative research on climate change adaptation in towns/cities and regions

The federal government's climate change impact research has yielded a variety of results, mostly field-tested, at local and regional level. The progress report included the results of a cross-evaluation of 12 research/funding programmes with 55 individual projects from the area of responsibility of five federal ministries. Some of these results are summarised below.

The development of the groundwork for action has advanced considerably and knowledge on climate change adaptation has become more robust. This applies in particular to regions and local authorities that were involved as case studies in the federal research project. These now have better information on climate impacts, vulnerability assessments, the climate change adaptation process, formal and informal instruments, and not least good practice. The cross evaluation resulted in the following cross-cutting conclusions:

- Climate impact prevention is carried out in many areas without it being classified as climate change adaptation, especially as it relates to flood protection, green development, avoidance of land sealing and heat preparedness.
- Component of integrated urban development. Climate change adaptation, where it is actively being addressed, is viewed as a cross-cutting task and as a long-term investment for minimising risk and improving quality of life in municipalities.
- Lack of resources. While large cities are in a position to carry out climate and vulnerability analyses that are costly both in terms of time and money, small municipalities often do not have the financial and human resources to initiate an adaptation process.
- Acting with uncertainty is possible. In projects and model projects, the development, planning and implementation of adaptation measures has been successful even with uncertainties (primarily as a result of no-regret/low-regret strategies).
- Pressure to act is still low. There is (still) no great pressure to act in most regions in Germany. The fact that people believe they are not affected to any great degree results in a lack of awareness of the problem when adapting existing strategies, standards, beliefs and behaviours.
- There seems to be no ideal adaptation process (one size fits all) for regions and municipalities, as they have very different starting circumstances and conditions. However, there are basic steps for climate change adaptation they need to take: understand climate change, determine the degree to which they are affected and assess climate change impacts, develop and implement measures, improve and observe the implementation of measures.
- DAS areas of action. With regard to DAS-related areas of action, in particular coastal protection, flood precautions/prevention, heavy rainfall, heat protection and drought, a number of examples of good practice were organised systematically and the results compiled in brochures for municipalities and regions. Some deal with specific issues and others cut across different fields of action.
- Uptake for federal support on offer. The participating actors responded positively to the funding programmes and model projects on climate change. Adaptation to

climate change, however, plays a rather minor role in planning practice, except in the model projects and municipalities.

A substantial number of tools, guidelines and methodology handbooks were developed in the federal research projects for the various phases of the adaptation process. They can support regions and municipalities in determining climate changes and impacts, adaptation opportunities and implementation strategies (e.g. Tatenbank (a catalogue of projects on the impacts of and adaptation to climate change), Klimalotse (climate guide), Stadtklimalotse (urban climate guide), Klimanavigator (climate navigator)).

The federal government will in future:

- Provide increased action-related knowledge over the long-term for policymakers and relevant actors and establish a comprehensive portfolio of federal climate services and adaptation services with a view to consolidating the DAS process and achieving strategic climate change adaptation goals;
- Continue to develop and implement policies and measures across sectors and ministries that help achieve DAS aims;
- Continue to promote the adaptation actions undertaken by local authorities and other actors;
- Increase its international engagement and support vulnerable developing countries in their adaptation efforts.

The Interministerial Working Group on Adaptation Strategy will continue to determine required actions, prioritise them and, based on this, update the Adaptation Action Plan regularly around every four years.

7.1.7 Progress and results of adaptation activities

As part of the first Adaptation Action Plan (APA I), the federal ministries submitted a list of planned and ongoing activities based on four priorities for action ('pillars'):

1. Pillar 1 'Providing knowledge, informing, enabling and inviting participation' is APA I's priority and comprises the federal government's information instruments. Pillar 1 aims to put actors in the various fields of action in a position to recognise and assess their own vulnerabilities to climate change and make decisions on the necessity of appropriate adaptation measures.
2. Pillar 2 'Framework-setting by the federal government' describes activities at federal level in further developing the legal frameworks for integrating adaptation into all policy fields of action. This comprises, for example, taking adaptation requirements into account in energy saving legislation or the compulsory inclusion of climate data in the risk assessments of financial services companies.
3. Pillar 3 'Measures for which the federal government is directly responsible' explains the adaptation measures taken by the government as an owner of properties, land and infrastructure, or as a developer. For instance, with regard to new builds and refurbishment of its existing properties, the federal government will assess in future if the buildings – in addition to reducing CO₂ emissions – also need to be adapted to the impacts of climate change.
4. Pillar 4 'International responsibility' describes the contribution that the German government is making to the implementation of international (or European) climate

change adaptation agreements and directives, as they arise from the Cancun Adaptation Framework under the United Nations Framework Convention on Climate Change, for example.

Progress and results achieved through APA I were assessed as part of the 2015 DAS progress report. The following is an excerpt from this report:¹⁸⁸

Of the 150 activities listed in the first action plan, 43 were already completed and 78 were still ongoing. Some measures have not been carried out to date (13) or were still in the preparation stage (10). The most frequently given reasons for this were that preparation and coordination took longer than expected in 2011 or there was a lack of personnel and financial capacities (see table 22).¹⁸⁹

	Total	Pillar 1	Pillar 2	Pillar 3	Pillar 4
Concluded activities	43	29	4	3	7
Ongoing activities	78	48	6	0	24
Activities in preparation	10	4	2	3	1
Activities not carried out	13	6	1	6	0
No entries	6	2	1	1	2

Table 23: APA implementation (as at October 2014)¹⁹⁰

7.1.8 Conclusion and next steps

There have been considerable advances in expertise at international and national level since DAS was introduced in 2008. This also means that the German DAS process has entered into its operational phase. The next step is to provide and safeguard the existing, academically recognised knowledge and data as a permanent resource.

Adaptation to climate change has now become a permanent task. For example, the federal government will continue to prepare regular reports on developments relating to climate change impacts and adaptation measures (monitoring report) and will determine the vulnerability to these impacts (vulnerability analysis). Furthermore, the federal government is planning to establish a comprehensive portfolio of climate and climate change adaptation services. To this end it developed a two-pillar approach that comprises a German Climate Service (Deutscher Klimadienst, DKD) and a portfolio of climate change adaptation services (KlimAdapt).

The federal government will also establish further frameworks through informal, economic and legal instruments. The informal instruments seek to establish information, cooperation and participation measures involving governmental and non-governmental actors. In future, the focus here will be on measures that improve information on the season- and region-specific impacts of climate change and the tailor-made options for action. Authoritative formal instruments will speed up the implementation of adaptation policy, for example with a view to making necessary differentiations in the stipulations in the regional development

¹⁸⁸ As at December 2015.

¹⁸⁹ The information is based on a self-assessment by the participating ministries. Measures that represented a long-term task or that were being transformed into one are assessed as 'concluded'.

¹⁹⁰ German government (2015).

plans and programmes. Corresponding federal government recommendations can be found in the second Adaptation Action Plan (APA II).

The next progress report on the national adaptation strategy is planned for 2020. The German government expects that it will be possible to implement the framework for the DAS evaluation by this date.

7.2 Climate modelling, projections and scenarios

The horizontal grid spacing of global climate models currently ranges from 120 to over 200 km, which means that the spatial resolution is not fine enough to be able to make any predictions about specific regions in Germany. The models are adequate for describing the fundamental variability of climate on a large scale, but the resolution does not allow a detailed presentation of differences in the extent of climate change in a specific region of the Earth (such as Germany). Therefore, methods are used to obtain a regional breakdown, which include regional climate models and information from individual calculations of global models.

The trends calculated differ, depending on the particular climate model and the initial and boundary conditions it uses. The resulting ranges of results produce uncertainties that must be considered when interpreting climate projections. Wider ranges require more cautious statements about subjects such as described signals of change.

Four representative scenarios or representative concentration pathways (RCPs) were chosen in preparation for the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).

This chapter discusses the results of simulation calculations based on a climate change mitigation scenario (RCP 2.6), a moderate scenario (RCP 4.5) and the “business-as-usual” scenario (RCP 8.5). The mitigation scenario (RCP 2.6) is based on assumptions that correspond to the political aim of limiting the increase in global mean temperature to 2 degrees Celsius. It assumes a scenario pathway that is associated with a very strong, very fast reduction in greenhouse gas emissions compared with current levels. Maximum radiative forcing (3.0 W/m^2) is reached before 2050. It then decreases continuously to 2.6 W/m^2 in 2100.

The business-as-usual scenario (RCP 8.5) describes a world in which the energy supply is primarily based on the combustion of fossil carbon stocks. Greenhouse gas emissions increase from today's level, and there is a constant rise in radiative forcing up to 2100. The moderate scenario (RCP 4.5) describes a lesser increase in radiative forcing and thus lies between the mitigation and business-as-usual scenarios. For purposes of comparison, the text mentions another scenario, SRES scenario A1B. It describes a world of strong economic growth and of population growth up to the middle of the century followed by a population decrease. The climate projection calculations of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) are based on this scenario.

Simulations with a horizontal grid mesh of 12.5 km are currently available for Germany. The results of 54 climate projection calculations covering the 1971-2100 period are used for this National Communication. Two 30-year periods are used to calculate the difference between the current situation and a future situation. An intermediate situation is calculated for each period. The 1971-2000 period from the models is used as the reference period for the observed climate. Two periods, referred to below as the short-term and long-term planning horizon, are analysed for the future. The short-term planning horizon describes the

intermediate situation for the 2021-2050 period. The basis for the long-term planning horizon is the 2071-2100 period. Future changes are stated as a mean value and a range. The range is delimited by the lowest and highest change values from the existing data sets.

7.3 Future climate changes in Germany

7.3.1 Temperature

A further rise in the temperature in Germany is expected (virtually certain, very high confidence*). ¹⁹¹ This increase is about 1.0-1.3 degrees Celsius for the short-term planning horizon (2021-2050) (likely, medium confidence). There is only a slight difference between the changes shown in the climate projections (mitigation scenario and business-as-usual scenario). The results range between 0.7 and 2.0 degrees Celsius. Warming is somewhat more pronounced in southern Germany.

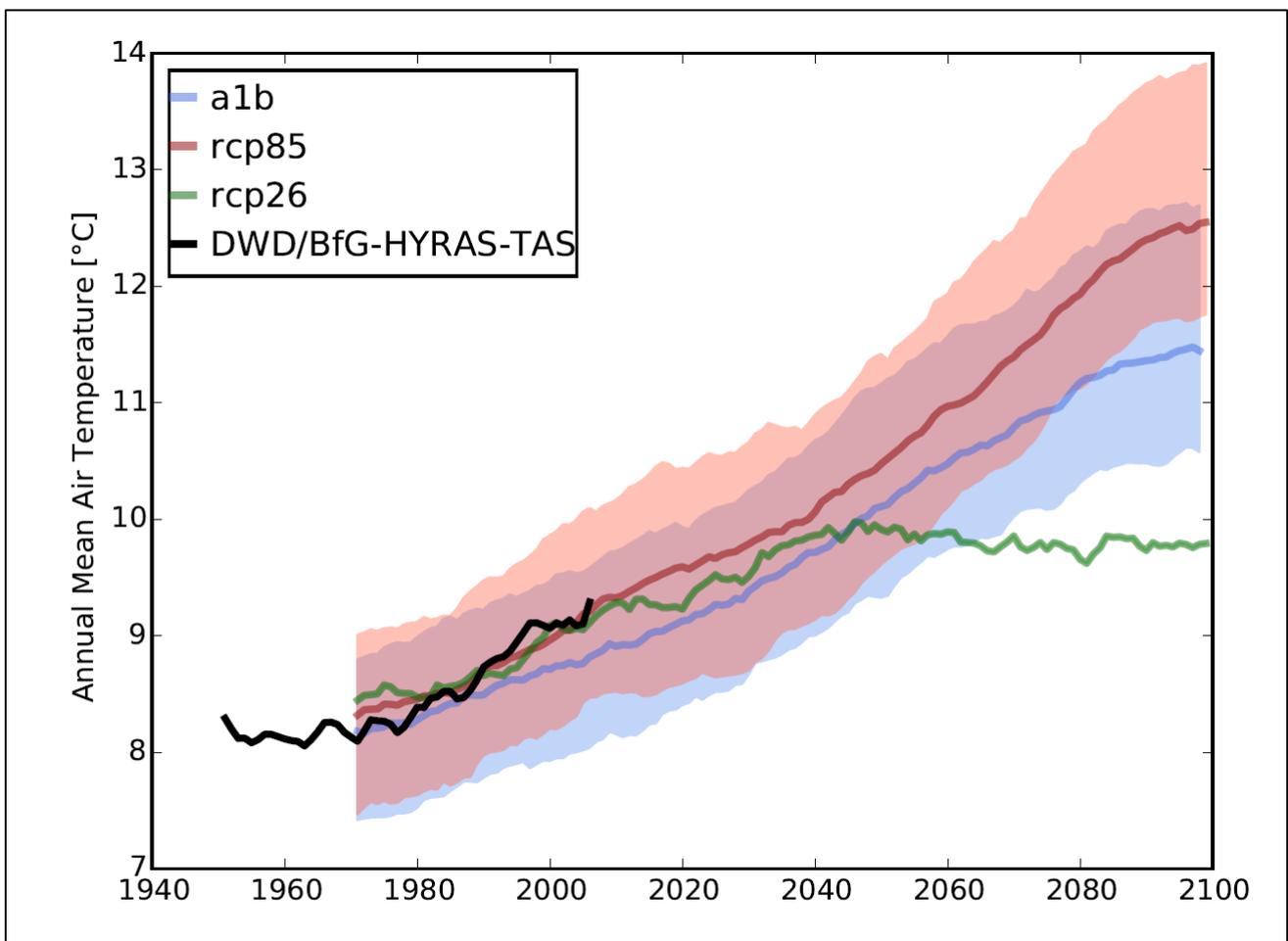


Figure 35: Trends in mean air temperature for Germany up to 2100 based on observational data (black) and ranges of possible trends in mean air temperature up to 2100 based on different emissions scenarios. ¹⁹²

The temperature trend for the long-term planning horizon is highly dependent on the chosen scenario. Based on the mitigation scenario, an increase of 1.1 degrees Celsius is expected (likely, medium confidence). Stabilisation at the level of the short-term planning

¹⁹¹ Information on the likelihood and confidence level of a finding or result is given in accordance with the guidelines and definitions in the Fifth Assessment Report of the IPCC.

¹⁹² Deutscher Wetterdienst DWD (to be published soon).

horizon results from the very strong reduction in greenhouse gas emissions within the defined scenarios. The change from pre-industrial levels is 2.4 degrees Celsius. There are hardly any regional differences. Warming is about 3.8 degrees Celsius under the conditions of the business-as-usual scenario (likely, medium confidence). The range of results is between 2.7 and 5.2 degrees Celsius. Warming is more pronounced in the southern regions. The results of the business-as-usual scenario roughly correspond to the results of the climate projection calculations based on SRES scenario A1B.

7.3.1.1 Regional differences

Particularly in the Alps, the projected warming rates under both the mitigation scenario and the business-as-usual scenario are greater than the changes projected for Germany as a whole.

The change there from the 1971-2000 reference period for the short-term planning horizon is between +1 degrees Celsius (mitigation scenario) and +2.2 degrees Celsius (business-as-usual scenario). Moderate warming rates between 1.1 degrees Celsius (mitigation scenario) and 4.5 degrees Celsius (business-as-usual scenario, likely, medium confidence) are projected for the long-term planning horizon.

In the coastal regions of the north-western and north-eastern German lowlands, the changes projected for the long-term planning horizon are below average values. Warming rates there are projected to be between 1 degrees Celsius (mitigation scenario, medium confidence) and 3.5 degrees Celsius (business-as-usual scenario, medium confidence, likely).

7.3.1.2 Seasonal differences

Warming is similar during the various seasons, with the exception of spring, when it is not as strong. As the temperature rises, there is a pronounced increase in temperature extremes. Extremes associated with low temperatures decrease sharply, while extremes associated with heat increase sharply (virtually certain, very high confidence).

The frequency of heatwaves will increase as a result. Warming in the Alps and the Alpine Foreland is more pronounced during all seasons than it is in Germany as a whole. Warming for the long-term planning horizon in winter, which averages 5 degrees Celsius (business-as-usual scenario, medium confidence, likely) is well above the warming rates of 4 degrees Celsius on average (business-as-usual scenario) projected for Germany as a whole.

7.3.2 Precipitation

An obvious change in total mean annual precipitation in the short-term planning horizon (2021-2050) is not expected for Germany (virtually certain, very high confidence). A 5 % increase in mean annual precipitation is calculated (*likely, medium confidence*). There is only a slight difference among the scenarios. The range of results is between a -2 % and +14 % change. It is about the same in all parts of Germany. Note that, as a matter of principle, a modelled change of less than 10 % cannot be distinguished from the natural variability in climate. That threshold applies to all values mentioned below.

7.3.2.1 Regional differences

In the long-term planning horizon (2071-2100), a 9 % increase in annual precipitation is anticipated for Germany (virtually certain, very high confidence). The extent of the change is approximately the same in all parts of Germany.

An increase in the number of days on which precipitation totals at least 10 mm is expected in all regions for both the short-term planning horizon and the long-term planning horizon. Some models project a decrease in days of this kind, but only in the Alpine region. The projected increase in the number of days on which precipitation totals 20 mm and above is less pronounced. However, for heavy precipitation, the range within the ensemble is in some cases so great that the results are not very reliable. Regional differences in the change in annual total mean precipitation are not very distinct.

7.3.2.2 Seasonal differences

For the short-term planning horizon 2021-2050, increases in precipitation between 5 and 7 % are calculated for the winter using all RCP scenarios (virtually certain, very high confidence). It is not possible to reach any conclusions about the trend for summer. Results range from slight increases to a slight decrease. During the transitional seasons, increases in mean total precipitation range from 3 % (autumn) to 8 % (spring) for this planning horizon (virtually certain, very high confidence).

In spring and autumn, the change in the long-term planning horizon (2071-2100) can range from +1 % to +13 % (virtually certain, very high confidence), while the change in winter can be as much as +17 % (likely, medium confidence). The amount of precipitation in summer calculated as an average across all scenarios decreases in this planning horizon. The decrease under the business-as-usual scenario (-7 %) is less pronounced than under the mitigation scenario (-4 %). The range under the business-as-usual scenario varies from a 20 % increase (*very low confidence, unlikely*) to a 50 % decrease (*very low confidence, unlikely*). The results for summer in the individual regions are also wide-ranging, so they do not appear very reliable. The results obtained in the business-as-usual scenario differ from those of the climate projection calculations based on SRES scenario A1B which were previously used. The long-term planning horizon in the business-as-usual scenario no longer includes the sharp declines in summer precipitation shown under SRES scenario A1B.

7.3.3 Monitoring the impacts of climate change

A monitoring system was developed for the German Strategy for Adaptation to Climate Change (DAS). The first monitoring report on the DAS was completed in February 2015. It uses 102 indicators to present the impacts of climate change that have already been observed and measured, as well as adaptation measures that have been initiated.

The term “adaptation” is broadly defined and includes measures that were not developed and implemented specifically in the context of adapting to climate change. What matters is that those measures generally support adaptation to climate change according to experts in the respective fields of action.

The 2015 Monitoring Report shows that the climate is also changing in Germany. This is revealed both by continuous changes and by the increased frequency of extreme weather events. The mean annual temperature is rising, and the vegetation period has increased from 222 days (1951-1980) to 230 days (1983-2012). Changes in seasonal weather patterns can have both positive and negative effects: for example, early blooming of apple trees increases the risk of damage from late frosts. In addition to the rising mean annual temperature, there has also been a rising trend of extreme heat events over the past 40 years. Preventive health measures as well as changes in urban planning and building methods and materials will be needed to reduce heat stress, particularly in cities. It affects

both biological and technical systems. Heat reduces the efficiency of electricity generation by thermal power plants and can cause problems related to cooling water extraction.

The more systems are influenced by people, the more difficult it is to distinguish which effects are the result of climate change and which are caused by changes in the usage or management of those systems. To choose the indicators, cause-effect relationships and their contribution to the adaptation process were discussed with and considered by experts.

The Monitoring Report is regularly updated. It provides data about climate-related changes in the various fields of action of the DAS which can already be measured and which could be used to develop adaptation measures.

7.4 Vulnerability to climate change

7.4.1 Vulnerability Network and vulnerability analysis for Germany

A vulnerability analysis was used as part of a screening process throughout Germany for the 15 fields of action of the German Strategy for Adaptation to Climate Change (DAS) and across fields of action to identify regions and systems that are at particular risk from – i.e. vulnerable to – climate change. The results of the vulnerability analysis¹⁹³ were published as a scientific report, and a summary was included in the first DAS progress report.

The Vulnerability Network was created by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) and the Federal Environment Agency (UBA) to provide scientific support in the development of the vulnerability analysis. It is made up of 16 higher federal authorities and institutions reporting to nine ministries and has the backing of a consortium supported by UBA and BMUB with funding from the latter. It was commissioned to prepare an up-to-date, consistent, cross-sectoral vulnerability analysis covering all of Germany to serve as a basis for prioritising climate risks. Crucial to the success of the network is the interdisciplinary cooperation of the sectoral research institutions and specialised authorities, which have the necessary data on specific fields of action and across multiple fields of action, the corresponding national mandates and the necessary expertise.

¹⁹³ Federal Environment Agency (2015c).

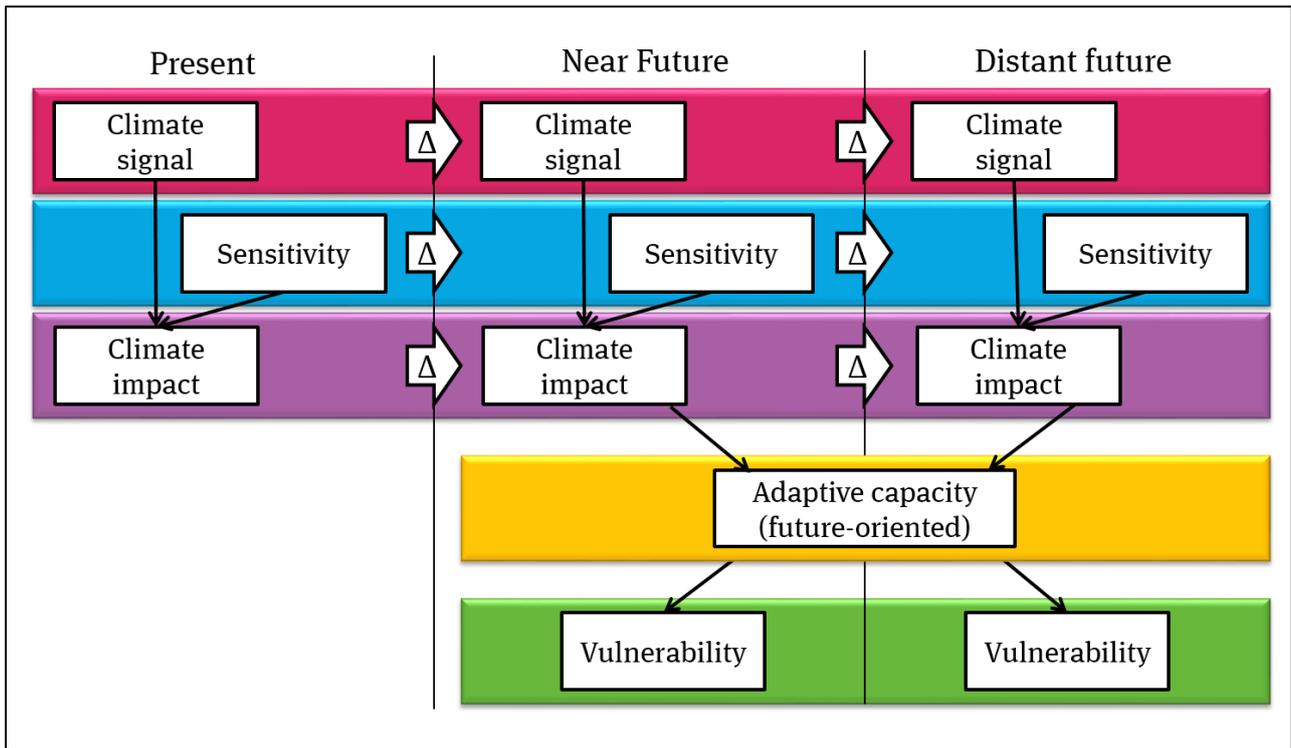


Figure 36: Vulnerability concept of the Vulnerability Network¹⁹⁴

The study was done for the present, the near future (2021-2050) and distant future. To map the range of future climate and socio-economic trends, two climate and socio-economic scenario combinations for the near future were investigated: strong change and weak change.

Of the 72 climate impacts rated as potentially relevant, 16 were explored using impact models, 23 using indicators and 40 using expert surveys concerning the strength and – where possible – the spatial distribution of current and future effects.

Possible sources of uncertainty could be at the level of the system understanding, the chosen indicator or model, and the data used.

When estimating adaptive capacity, potentially available resources were taken into account, but not the actually existing economic and technical capacity of the ministries, specific institutions or individual players.

The vulnerability of each field of action is shown by the summary of the evaluation of the importance of the climate impacts in that field of action carried out in the network minus the adaptive capacity of the specific field of action. Comments on the vulnerability of individual fields of action, based on the summary of evaluations and reviews of different quality, inevitably produce a rather rough estimate.

7.5 Results of the vulnerability analysis

The primary results of the analyses and evaluations done by the Vulnerability Network can be summarized in six major areas impacted by climate change across all fields of action (see Figure 33 on the regional involvement and consequences of climate change across all fields of action in Germany):

¹⁹⁴ German government (2015).

1. Damage caused by rising heat stress in agglomerations
 - Particularly affected fields of action: human health and the building industry
 - Areas primarily affected: densely populated areas in warm regions, which will continue to spread in the future
2. Adverse effects on water use through increased warming and (in the distant future) increased summer drought
 - Particularly affected fields of action: soil, forests and forestry and the energy industry
 - Areas primarily affected: regions with a warm, drier climate in eastern Germany and the Rhine basin
3. Damage to buildings and infrastructure through heavy rains and flash floods in urban areas
 - Particularly affected fields of action: water management, water balance, coastal and marine protection, building industry, transport, transport infrastructure and industry and commerce
 - Areas primarily affected: densely populated areas in the north-west German lowland, low mountain range regions and south-west Germany
4. Damage to buildings and infrastructure by river flooding
 - Particularly affected fields of action: water management, water regime, building industry, transport, transport infrastructure, and industry and commerce
 - Areas primarily affected: densely-populated areas in river valleys of the northern German lowland, as well as the Rhine and Danube basins
5. Damage to coasts due to a rise in sea levels (increasing in the distant future) and the subsequent increased swell and rising storm surge risk
 - Particularly affected fields of action: coastal and marine protection, the building industry, transport, transport infrastructure and industry and commerce
 - Areas primarily affected: coasts
6. Changes in the composition and the natural development phases of species due to a gradual increase in temperature
 - Particularly affected fields of action: human health, soil, biodiversity, agriculture, forests and forestry and fisheries
 - Areas primarily affected: Oceans and rural areas

The increase in heat stress is the clearest, strongest climate signal and has considerable effects on health and infrastructure, particularly in densely-populated areas. At the same time, water management, agriculture and forestry are particularly threatened by increasing heat and by drought in the distant future. The areas of Germany that are most vulnerable to climate change are those with socio-economic deficits which are located in regions with a warm climate and are therefore most exposed to heat and drought.

Other vulnerable regions are densely-populated, structurally-weak areas, large parts of which are at risk of flooding due to the expected increase in heavy summer rainfall and winter precipitation. They could be affected both by river flooding and by flooding or flash floods caused by heavy rainfall.

Over the long term, it is particularly the coastal regions and the species and habitats tied to unique, sensitive regions such as the Wadden Sea and high mountain ranges which will be threatened by the gradual temperature increase.

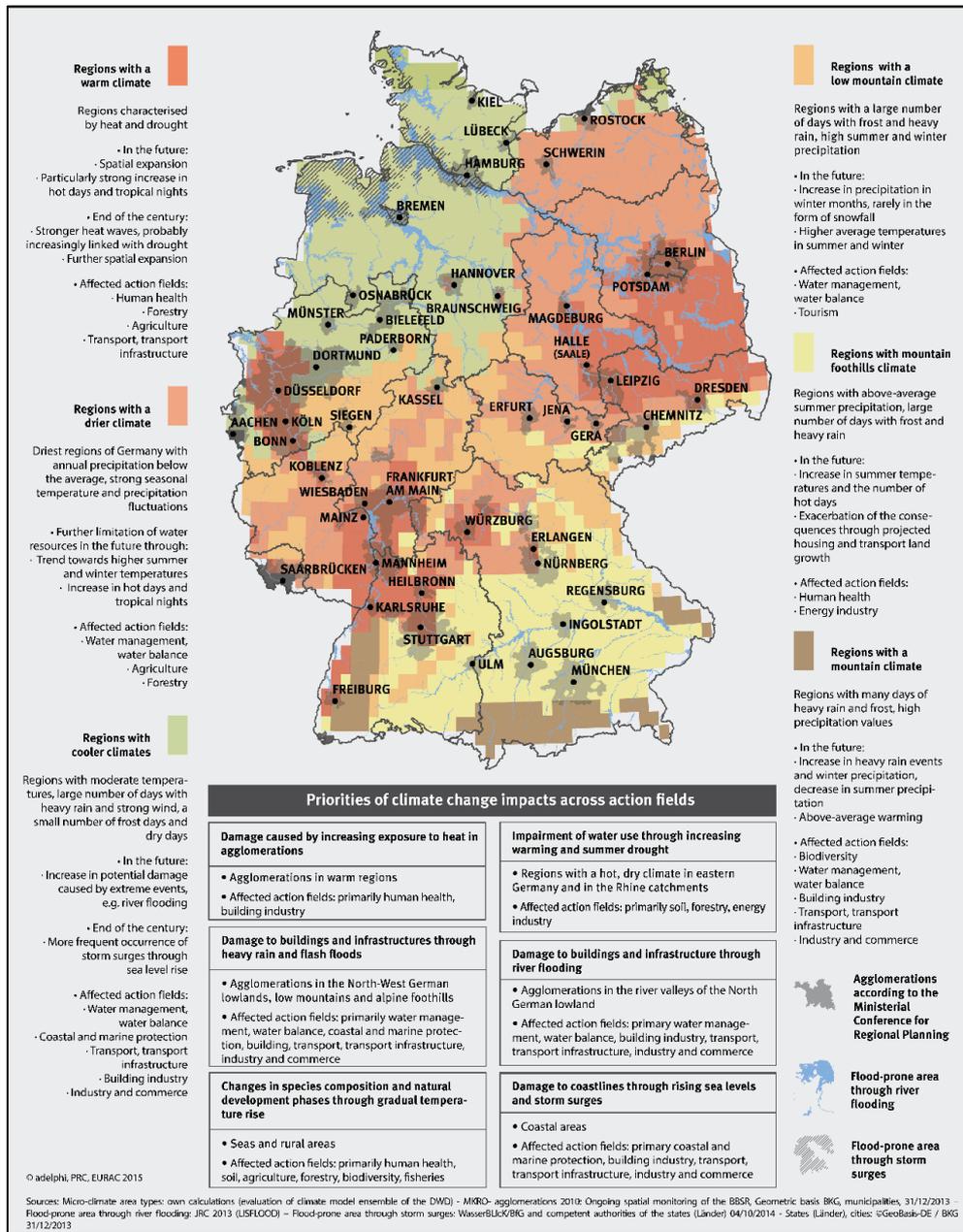


Figure 37: Regional involvement and consequences of climate change across all fields of action in Germany¹⁹⁵

¹⁹⁵ UBA (2016b).

7.6 Monitoring and evaluation

7.6.1 Evaluation of the German adaptation strategy

The evaluation of the German strategy for adaptation to climate change is based on methodological preparation and coordination by the committees of the German government and Länder which are responsible for steering the process (Interministerial Working Group, Permanent Committee on Adaptation to the Consequences of Climate Change).

The evaluation includes both the strategic level and the level of measures outlined by the DAS. Progress in developing the strategy will also be determined based on an impact evaluation. Starting in summer 2017, the developed method will be used to evaluate whether the DAS represents a successful strategic approach that can be used to achieve the established policy objectives of the individual fields of action, including when climatic conditions have changed. The overarching goal of the evaluation of the DAS process is to gain the knowledge needed to further develop and improve the process. Based on the overarching goals, the evaluation explores three main questions, using a process evaluation to consider the DAS process at the strategic level, particularly the development process, the interaction of the participating players, and relationships between documents and projects or activities.

A second key question relates to the extent to which adaptation measures have been implemented at federal government level. The focus of this part of the evaluation is on the Adaptation Action Plan (APA II), because it indicates the current progress of measures taken by the German government and contains all of the important information about requirements for action and the climate impacts being addressed. In addition to the question concerning progress in implementing measures, the question of what factors contribute to successful implementation and what challenges face the responsible entities and participating actors involved in implementation will also be explored.

A third part will cover the question of the effectiveness of DAS. It will also focus on the measures of APA II. The question relating to all of these is whether the DAS or the measures of APA II will be successful in helping to reduce vulnerability and increase the adaptive capacity of natural, societal, and economic systems in Germany.

8 Research and systematic observation

8.1 Fundamental orientation, financing and research landscape

As well as presenting the task of broadening and securing the knowledge base on climate change and its consequences, the goals agreed as part of the Paris climate agreement pose new challenges for policy-related climate research. Furthermore, over the next two decades decisions will be taken that set the direction for implementing the global sustainable development goals, including those relating to climate change mitigation and adaptation to climate change.

Research on sustainability, including global change, is mainly funded in Germany by the Federal Ministry of Education and Research (BMBF) and the German Research Foundation (DFG). Funding is awarded either to specific projects or entire institutions. In the institutional field, funding for climate research extends to various institutes within the Helmholtz Association of German Research Centres (HGF), the Max Planck Society (MPG), the Fraunhofer-Gesellschaft (FhG) and the Leibniz Association (WGL). Further details of the research landscape are given below. Since 2013 the German Committee Future Earth (DKN Future Earth) has been working as an advisory body on international developments and activities in connection with the global research initiative Future Earth.

BMBF supports sustainability research in various fields, including environmental aspects of sustainability, primarily in what is now the third Research for Sustainable Development framework programme (FONA³). The FONA framework programme implements Germany's National Sustainable Development Strategy and the government's new High-Tech Strategy. They contribute to achieving the emission reduction targets, and to the targets for expanding the use of renewables and increasing energy efficiency. Other goals to which sustainability research will contribute include doubling resource productivity and reducing the rate of additional land take per day from 130 to 30 ha.

Germany's new High-Tech Strategy will enable it to maintain and consolidate its position as a technological leader in climate change mitigation and adaptation to climate change, sustainable natural resource management and innovative environmental and energy technologies. Here, too, FONA³ will play a crucial part. Climate-friendly and environmentally sound development also offers unique opportunities for business: climate change mitigation, resource efficiency and renewable energy supply are the lead markets of the future.

The German government promotes research and development in forward-looking energy technologies in the fields of renewables, energy efficiency and the energy system through its 6th Energy Research Programme, for which three ministries are responsible: the Federal Ministry for Economic Affairs and Energy (BMWi), the Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry of Education and Research (BMBF). Support focuses on helping companies and research institutions to conduct research on new technologies for future energy supply and to develop those technologies. The 6th Energy Research Programme defines the current principles and priorities for federal government funding for innovative energy technology. Assistance is aimed specifically at technologies that meet the requirements of the energy transition. The funding for key areas – energy efficiency and renewable energy – places the emphasis on technologies used to generate electricity with wind and photovoltaic systems, increasing the share of renewables in the heating sector, energy-optimised buildings and neighbourhoods, and energy efficiency in

industry. It particularly focuses on systemic solutions for the integration of new energy supply technologies, new grid technologies, energy storage and sector coupling.

In addition to contributions designed to drive down costs and achieve security of supply in implementing Germany's energy transition, considerable efforts are being made to mobilise private-sector research capacity and capital to speed up innovation processes for climate change mitigation and make products and services ready for the market as soon as possible. In addition to the Energy Research Programme, innovation alliances have been launched, for example as part of the High-Tech Strategy for Climate Protection.

The Federal Ministry of Food and Agriculture (BMEL) promotes research projects relevant to climate change mitigation and sustainability under a range of funding programmes: renewable resources, innovation, the promotion of organic farming, international forestry research and global food and nutrition security research. Over 60 % of the research projects conducted by BMEL's sectoral research institutes make a direct contribution to helping climate change mitigation in agriculture, horticulture, forestry, fisheries and the food industry.

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) promotes sectoral research supporting the development of scientific backing for decisions on action in environmental and construction policy, the drafting of strategies and concepts, the assessment of environmental impacts, and monitoring and evaluating social, economic and technological trends. Statutory regulations have to be reviewed and refined and ongoing programmes and strategies require backup through research.

One aspect of the sectoral research undertaken by BMUB is to investigate ways in which social change can be helped to move in the direction of sustainability. Current research focuses principally on climate change mitigation, adaptation to the impacts of climate change, resource efficiency and the circular economy, sustainable product and consumer policy, the environment and the economy, the protection and conservation of groundwater and surface waters, soil conservation, marine protection and flood protection. Other issues covered include air pollution control, noise control, sustainable mobility, the environment and health, but also chemical safety, nature conservation, nuclear safety and radiation protection.

Findings from climate impact research, which investigates the interactions between changes to the climate on the one hand and natural systems and human society (socioeconomic systems) on the other, form the scientific basis for specific climate change adaptation measures. They also form the basis for evaluating the risks associated with human influence on the climate system and therefore for setting mitigation goals.

There is also a continuing need to improve our fundamental understanding of certain highly complex processes within the climate system so that they can be reliably represented in climate models. This means that new, high-resolution observation data is essential. In other cases, more efficient methods need to be found to enable the processes to be adequately taken into account in computer models. To improve this knowledge base, new observation methods and systems are constantly being established and research to achieve a better understanding of the underlying processes is being done by BMBF, DFG and the Helmholtz Centres, including the Max Planck Institute for Meteorology and the Helmholtz Climate Initiative REKLIM, a consortium of nine research centres within the Helmholtz Association.

BMBF and BMVI are supporting work to continue developing the regional climate model COSMO-CLM and new multi-scale models such as ICON. The aim is to continue to

improve their suitability for use as input datasets for high-resolution model simulations for assessing the impact of climate change. To identify the full scope of future climate trends, ensemble analyses are being further refined in order to obtain forecasts of probability on the basis of all available regional climate simulations for Germany based on the IPCC RCP (representative concentration pathways) scenarios.

Predictions about the scope of possible future climate changes, both spatially and over time, accompanied by information about the associated probability, provide an important foundation for adaptation research and decisions.

In developing a model system for predicting climate trends, BMBF is creating the methodological foundation for decadal climate prediction (MiKlip I and II). The aim is to develop reliable predictions with time scales of up to ten years for the climate in Central Europe (and Africa), including its extremes as influenced by natural climate fluctuations and anthropogenic climate changes. These time scales play a key role in planning processes, especially in business. BMBF is currently implementing this funding measure on decadal climate prediction. This activity is incorporated into the cooperation with European countries within a Joint Programming Initiative entitled Connecting Climate Knowledge for Europe (JPI Climate).

8.1.1 Institutional research landscape

Weather and climate research in Germany is already a well-developed field. More than ten university institutions, the Max Planck Institutes for Meteorology (Hamburg), Biogeochemistry (Jena) and Chemistry (Mainz), various centres that belong to the Helmholtz Association (HGF), institutions within the Leibniz Association (WGL) and sectoral research institutions reporting to government ministries conduct world-class climate research with the support of the German Climate Computing Centre (DKRZ).

There are plans for non-university research that is financed or co-financed through institutional funding (HGF, MPG, FhG, WGL) to be more closely linked with the research funding organisations and for their collaboration with universities to be funded.

The mission of the Helmholtz Association (HGF) is to pursue the government's and society's long-term research objectives and preserve and enhance the resources that sustain life. To do this, it identifies and explores issues concerning society, science and business by conducting strategic cutting-edge research programmes in six areas: Energy; Earth and Environment; Health; Key Technologies; Matter; and Aeronautics, Space and Transport.

A number of Helmholtz Centres contribute their expertise in the research area that is of relevance here, Earth and Environment:

- Alfred Wegener Institute for Polar and Marine Research (AWI)
- German Aerospace Center (DLR)
- Forschungszentrum Jülich (FZJ)
- Karlsruhe Institute of Technology (KIT)
- Helmholtz Centre for Infection Research (HZI)
- Helmholtz Centre Potsdam – German Research Centre for Geosciences (GFZ)
- Helmholtz-Zentrum Geesthacht Centre for Materials and Coastal Research (HZG)

- Helmholtz Zentrum München – German Research Center for Environmental Health (HMGU or HZM)
- Helmholtz Centre for Environmental Research – UFZ
- Helmholtz-Institut Climate Service Science (HICSS) with its partners GERICS (Climate Service Center Germany) and Universität Hamburg (natural, social and economic sciences)

The Helmholtz Association's Earth and Environment research field examines the basic functions of the Earth as a system and the interactions between nature and society. It is divided into five programmes related to climate change:

- Geosystem: the changing Earth
- Marine, coastal and polar systems
- Oceans
- Atmosphere and climate
- Terrestrial environment

The work focuses on expanding and linking up long-term observation systems, building scientific expertise and capacity, providing an internationally competitive research infrastructure, improving models and forecasts and transferring results to society. A particularly important goal is to develop recommendations for action to ensure that the Earth's resources are used sustainably without destroying the very foundations on which life depends. An important component of the work is to establish and operate infrastructure such as the HALO research aircraft and the TERENO network. The latter involves constructing terrestrial observatories in four selected regions in Germany. COSYNA is a project to create a long-term observation system for the German North Sea, later to be extended to the Arctic, that can provide an operational and synoptic description of the environmental status of coastal waters in the North Sea and the Arctic. One key motivation behind COSYNA is the desire for continuous provision of near real-time and post-processed products bridging the gap between operational oceanography and the various users of forecasts of the state of the sea.

To meet the challenges, the Earth and Environment research field will continue to pool the capacities of the participating centres within shared research portfolios. This strategy creates new alliances and facilitates the expansion of Earth observation and knowledge systems, as well as integrated modelling approaches. The aim is to help society to cope with the complex challenges brought about by changes in the Earth system.

The activities of the framework programme are linked with the Helmholtz Association's research programmes – in particular with Earth and the Environment, Energy and Key Technologies – in such a way that the Association can contribute infrastructure services and research that is designed to be longer term and broad based.

The Earth and Environment research field explores key themes in projects that cut across the different research fields to make systematically generated knowledge accessible for policymakers and society as a whole. The key themes include Earth observation, climate research, mineral resources, bioeconomics, geoenergy and resource-efficient and climate-adapted cities.

Within the Leibniz Association (WGL), a whole series of other institutes also enrich the German climate research landscape with their scientific, technical and socioeconomic expertise:

- German Institute for Economic Research (DIW) Berlin: political sustainability strategies and measures, analysis of energy markets and renewable energy
- Leibniz-Institute of Atmospheric Physics (IAP) Kühlungsborn: physics of the middle and upper atmosphere
- Ifo Institute – Leibniz Institute for Economic Research at the University of Munich: environmental economics research, analysis of climate and energy policy instruments and markets
- Leibniz Institute for Tropospheric Research (IfT) Leipzig: tropospheric research, chemical changes in trace substances, exchange of substances in the atmosphere, aerosols – interactions with clouds and radiation
- Kiel Institute for the World Economy (IfW): international climate policy, environmental policy instruments, sustainable development
- Leibniz Institute for Baltic Sea Research (IOW) Warnemünde: Baltic Sea research, transport and transformation processes in the sea, marine communities and material cycles, changes in marine ecosystems
- Halle Institute for Economic Research (IWH): new technologies and resource efficiency
- Leibniz Centre for Tropical Marine Research (ZMT)
- Museum für Naturkunde – Leibniz Institute for Evolution and Biodiversity Science (MfN), Berlin
- Potsdam Institute for Climate Impact Research (PIK) Potsdam: climate impact research, systems analysis, global change and natural systems, global change and social systems
- RWI – Leibniz Institute for Economic Research, Essen: evaluation of environmental and energy policy instruments
- Senckenberg Gesellschaft für Naturforschung (SGN), Frankfurt am Main
- Leibniz Centre for Agricultural Landscape Research (ZALF) Müncheberg: agricultural and landscape research
- Centre for European Economic Research (ZEW), Mannheim: economic analysis of environmental – especially energy and climate – policy instruments
- Zoological Research Museum Alexander Koenig – Leibniz Institute for Animal Biodiversity (ZFMK), Bonn

The Fraunhofer-Gesellschaft (FhG) focuses its research on all fields of engineering. It is applications-oriented and works closely with industry. FhG's contribution to mitigating climate change and its effects stems mainly from its work on restructuring the energy industry. The main issues that the Fraunhofer Energy Alliance works on include development of efficiency technologies, use of renewable energy sources and, more recently, developing technology to pave the way for more electromobility. This group, which has 18 member institutes, also works on building-service technologies, smart energy grids and storage and microenergy technology. The members are the following Fraunhofer Institutes:

- Building Physics (IBP), Stuttgart
- Chemical Technology (ICT), Pfinztal
- Factory Operation and Automation (IFF), Magdeburg
- Interfacial Engineering and Biotechnology (IGB), Stuttgart
- Integrated Circuits (ISS), Erlangen
- Integrated Systems and Device Technology (IISB), Erlangen
- Advanced System Technology (AST), Illmenau
- Ceramic Technologies and Systems (IKTS), Dresden
- Manufacturing Engineering and Automation (IPA), Stuttgart
- Physical Measurement Techniques (IPM), Freiburg
- Silicate Research (ISC), Würzburg
- Silicon Technology (ISIT), Itzehoe
- Solar Energy Systems (ISE), Freiburg
- Fraunhofer Center for Sustainable Energy Systems (CSE), Cambridge, USA
- Systems and Innovation Research (ISI), Karlsruhe
- Environmental, Safety and Energy Technology (UMSICHT), Oberhausen
- Mechanics of Materials (IWM), Freiburg, Halle
- Wind Energy and Energy System Technology (IWES), Bremerhaven, Kassel

Under their statutes, the sectoral research establishments that receive institutional funding from BMEL have the task of preparing scientific decision-making aids for food, agriculture, forestry and fisheries policy and thus at the same time of broadening scientific knowledge in these fields for the benefit of the common good. In particular the monitoring tasks performed for many years by BMEL's federal research institutes (for example on the condition of forests, biodiversity, fish stocks, the condition of soil and animal health) and scientific analyses based on the observed data generate valuable insights and recommendations for policy and practical action in respect of climate change mitigation and adaptation to climate change. The institutions listed below (which between them have over 3,000 employees) use varying shares of their capacity to conduct research into climate change mitigation and/or adaptation to climate change, with different points of emphasis:

- Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (TI)
- Julius Kühn Institute, Federal Research Centre for Cultivated Plants (JKI)
- German Biomass Research Centre (DBFZ)
- Friedrich Löffler-Institut, Federal Research Institute for Animal Health (FLI)
- Max Rubner-Institut, Federal Research Institute of Nutrition and Food (MRI)
- German Federal Institute for Risk Assessment (BfR)

8.2 Research

8.2.1 Research on the climate system, variability and interactions in the Earth system

A systematic link between modelling and observation is crucial to achieving further progress towards understanding the climate system and in particular its variability and the interactions between the components of the Earth system. To ensure that the measurement data is highly informative, the German government is therefore focusing on continuous long-term observation of processes in the atmosphere and the oceans and on land. In addition, it facilitates detailed investigation of key processes, for example by the modern research aircraft HALO and POLAR 5, Neumayer III Antarctic research station and the fleet of German research ships. Their in-situ and remote-sensing observation techniques complement routine global recording of the key parameters of the global climate system. Innovative space technology can help monitor compliance with environmental agreements and provide the data needed to improve predictions about climate change and its effects.

Germany participates in international research programmes through numerous projects funded by BMBF: World Climate Research Programme (WCRP), International Geosphere-Biosphere Programme (IGBP), Global Earth Observation System of Systems (GEOSS), Global Climate Observing System (GCOS), Copernicus (formerly Global Monitoring for Environment and Security (GMES)) and UN maritime policy (e.g. RIO+20, UN 2030 Agenda).

Germany is already the leading European participant in space-based climate research and Earth observation: German missions such as the TerraSAR-X radar satellite, the RapidEye optical satellite system and the EnMAP satellite, which is already at an advanced stage of development, monitor global phenomena such as the state of the polar ice caps, the major continental glaciers, deserts, rain forests and oceans.

GRACE is a joint German-American gravity field satellite programme that generates an updated, high-precision image of the Earth's gravity field every month. The findings about the distribution of mass within the Earth and on the Earth's surface can be used to obtain information about ocean currents, for example, or the melting of glaciers. A GRACE Follow-On mission (GRACE-FO) is at the planning stage; two satellites are due to enter orbit in 2018 to continue this highly successful mission.

From 2021, the Franco-German MERLIN satellite project will measure the global distribution of methane – an extremely important greenhouse gas – in the atmosphere. The European Space Agency's Climate Change Initiative (ESA CCI) will also make a significant contribution to standardising global climate data. Germany is financing about a third of this European programme. With France and Germany as lead countries, development is continuing of the second and third generation of the European weather satellite systems, Metop and Meteosat Third Generation (MTG) respectively. They will be launched at the end of the decade and will continue observations from about 2022 onwards. Finally, the European Earth Observation Programme Copernicus is making a considerable contribution to monitoring the climate system and forecasting the effects of climate change. Current plans for launching the Sentinel satellites extend until 2029. The process of setting up six special services to supply important data products on a routine basis, among other things on climate issues, has now begun. Here, too, Germany is playing a leading role in the European alliance. To improve management of the German contributions, national coordinators were appointed for each of the six Copernicus services (Land Monitoring, Maritime Environment Monitoring, Emergency Management, Atmosphere Monitoring,

Climate Change and Security) with BMVI as lead agency, and funding measures were initiated, national Copernicus forums were held and an online information service was set up.¹⁹⁶ The Copernicus Data and Exploitation Platform – Deutschland (CODE-DE) is Germany's Copernicus entry point for satellite data from the Sentinel family and the information products of the Copernicus services. The CODE-DE platform has provided a quick and easy means of retrieving the latest data from the Sentinel 1a and b, Sentinel 2a and Sentinel 3a satellite systems online since 9 March 2017.

8.2.1.1 Atmosphere

Monitoring the atmosphere is part of the remit of Germany's National Meteorological Service (Deutscher Wetterdienst, DWD). To this end it operates extensive observation networks, which include conventional meteorological and climatological observation stations as well as a network of weather radars. Germany also plays a significant role in EUMETSAT, the European operator of operational meteorological satellite systems. Monitoring the climate is also part of EUMETSAT's mandate.

Measures to improve understanding of the climate system (especially internal variabilities and important interactions with the anthropogenic greenhouse effect) and improve modelling (global, regional and local) are promoted under BMBF's Research for Sustainable Development framework programme (FONA³). The aim is to be able to predict short-term climate changes (up to 10 years), generate more accurate simulations of longer-term climate scenarios and be better able to estimate trends in extreme climate events.

The research initiatives are complemented by targeted funding for research and monitoring infrastructure measures, for instance for ground-based and aircraft-based measurement of trace gases relevant to the greenhouse effect. Support was provided for the German contribution to the European Integrated Carbon Observation System (ICOS), for example. This involved setting up efficient and quality-assured measuring infrastructure for the most important climate-relevant trace gases and transferring it to the operational users at the end of 2016.

Another observation platform on aircraft is currently being set up with funds from BMBF and several research institutions (In-service Aircraft for a Global Observing System – IAGOS). There are now ten commercial airliners flying long-distance routes that carry measuring instruments to monitor the composition of air in the lowest layer of the Earth's atmosphere, at altitudes of between 3 and 13 km. Fully automatic measurements are taken of certain atmospheric parameters: ozone, carbon monoxide, humidity and cloud particles. Soon the measurements will also include the greenhouse gases carbon dioxide (CO₂), methane (CH₄) and water (H₂O), as well as nitrogen oxides, reactive nitrogen compounds and aerosols. The aim is to run measurements with a fleet of 20 aircraft operating worldwide.

A new field of research focusing on the joint use of measurement data and models concerns the determination of emissions of climate-relevant trace gases. German researchers launched a first major field experiment in this field in 2017 (AIRSPACE/CoMet), involving BMBF, DFG and various research institutions.

Optimised, synergistic use of data from all the observation systems will be achieved through the process of data assimilation as a component of numerical weather forecasting systems. This approach can also be used with model-based re-analyses in order to achieve a consistent description of atmospheric parameters over longer periods of time. The

¹⁹⁶ www.d-copernicus.de

European Centre for Medium-Range Weather Forecasts (ECMWF), which Germany is involved in, uses this approach for the global atmosphere. A higher spatial resolution can be achieved using regional re-analyses. This approach is currently being trialled at the Hans Ertel Centre for Weather Research, which is part of Germany's National Meteorological Service, the Deutscher Wetterdienst (DWD), and is located at Bonn University. Developments to improve decadal climate predictions and projections are taking place at a number of German research institutions.

8.2.1.2 Marine and polar research

German climate, marine and polar research has a multifaceted infrastructure comprising research ships, polar stations, observatories and research satellites which, in conjunction with internationally oriented project funding from the Federal Ministry of Education and Research (BMBF), supplies important climate observation data and trend data that is regularly used by the Intergovernmental Panel on Climate Change (IPCC) as the basis for its climate reports. Technical and societal innovations are needed to respond to climate change.

The aim of BMBF funding activities is to obtain a better understanding of the processes and changes in the "Earth system" on a global and regional scale and to investigate aspects such as forecasting, precaution against risk, environmental conservation and sustainable use. The main themes in coastal, marine and polar research are:

- The role of the oceans in the global climate system (storage and transport of heat, CO₂ storage, ocean currents);
- Changes in the Antarctic and Arctic regions (above all the Arctic: influence on the European climate, changes to future use);
- The threat to marine ecosystems from climate change and anthropogenic influences (ocean acidification, changes to ocean currents, influence on biodiversity and biomass production);
- Changes to coastal zones resulting from human influence and climate change; integrated coastal zone management, coastal engineering (rising sea levels);
- Marine mineral, biological and energy resources (availability, sustainable use strategies, accompanying environmental research).

The German research projects are integrated into international research programmes and United Nations conventions, as well as European policies. In addition to the themes listed above, BMBF promotes the development of innovative marine measurement technology for the long-term observation of changes in the marine environment.

In light of the multiple points of intersection between widely differing disciplines of science and technology, for example in coastal research, the use of marine resources and research on dealing with natural hazards, it is essential for there to be close coordination with related programmes – not only those run by BMBF but also those implemented by universities and other ministries.

BMBF's Research for Sustainable Development framework programme (FONA³), published in early 2015, is underpinned by specific sectoral programmes on coastal, marine and polar research (MARE:N) and geoscientific research (GEO:N). The MARE:N programme was

published by Federal Minister for Education and Research Johanna Wanka on 8 June 2016.¹⁹⁷

MARE:N is targeted at climate-related coastal, marine and polar research and at research into the protection and sustainable use of coastal, marine and polar areas. The preventive research carried out under MARE:N is intended to improve the state of the environment in the oceans and seas, and in the polar regions, while at the same time pointing the way forward for the long-term use of natural resources and ecosystem services. Both interdisciplinary and transdisciplinary research is planned, with consideration for social aspects too.

In recent years BMBF has made a significant contribution to climate research through three major collaborative projects: (1) Regional Atlantic Circulation and Global Change (RACE), (2) Biological Impacts of Ocean Acidification (BIOACID) and (3) Surface Ocean Processes in the Anthropocene (SOPRAN).

With its marine and polar research activities, the German government contributes to implementing its internationalisation strategy, in particular the general goals of taking international responsibility in tackling global challenges and strengthening cooperation with developing countries in the fields of education, research and development. Particularly noteworthy in this context is its cooperation with Indonesia, Russia, China, South Africa/Namibia and Israel.

BMBF plays a key role in the European Joint Programming Initiative on Healthy and Productive Seas and Oceans, and in ERA-Net BONUS. The aim of these activities is to pool national and EU capacities with a view to creating a solid basis in marine science to ensure sustainable use of marine resources, predict the effects of climate change on the seas and oceans and develop adaptation strategies.

Under the aegis of the Thünen Institute, the Federal Research Institute for Rural Areas, Forestry and Fisheries, BMEL maintains three specialist institutes, Fisheries Ecology, Sea Fisheries and Baltic Sea Fisheries, in Hamburg, Bremerhaven and Rostock respectively. The institutes each have their own research ships and are particularly involved in carrying out monitoring tasks within international research networks.

8.2.1.3 Hydrological cycle

The global hydrological cycle is a key element in the climate system. To achieve sustainable management of ecosystems it is essential that, in attempting to address questions of the availability, quality and distribution of water in different climate zones, the causes and effects of changes in the Earth's hydrological cycle are precisely understood against the backdrop of changes occurring on a global level.

Addressing the upcoming challenges calls for new conceptual approaches and more particularly innovative technologies. With this in mind, the German government in its new High-Tech Strategy – Innovations for Germany and BMBF with its Research for Sustainable Development framework programme (FONA³) have established a key line of action, the main feature of which is the way it links basic and application-oriented research. The programme focuses on the sustainable water management sector with its strong growth potential, along with resource and energy efficiency.

BMBF's funding for water issues has been consolidated in its Sustainable Water Management (NaWaM) priority research area since 2011. NaWaM addresses five separate

¹⁹⁷ Federal Ministry of Education and Research (2016).

fields, for which calls for funding proposals have been published at regular intervals to date, namely water and energy, water and nutrition, water and health, water and the environment, and water in urban areas. BMBF is providing a total of EUR 200 million in funding for NaWaM.

Since 2014, BMBF has been funding 12 collaborative projects under the Future-oriented Technologies and Concepts for Energy-efficient and Resource-saving Water Management (ERWAS) programme. The solutions ERWAS is seeking to develop are aimed at achieving more efficient and economical use of energy and at sustainable energy generation on the basis of better use of available resources (such as the energy content of wastewater).

The Future-oriented Technologies and Concepts to Increase Water Availability by Water Reuse and Desalination (WavE) funding programme has been in place since 2016. Its purpose is to develop innovative technologies, processes and management strategies to treat, desalinate and reuse water with the efficient employment of resources and energy, which it is doing in 13 joint research projects. WavE is thus making a significant contribution to reducing energy demand and CO₂ emissions while also increasing water availability.

Water as a global resource (GROW) is an internationally oriented funding measure with which since March 2017 BMBF has been supporting 11 joint projects on improved, forward-looking management of water resources in the face of intensifying pressure on use. The focus is on improving governance in the water sector, paying explicit attention to the interaction between global climate and water regime issues on the one hand and regional and local measures on the other (in particular the energy sector, irrigated agriculture, wastewater systems and trade incentives).

8.2.1.4 Land surface and land use

Scientific interest is increasingly focusing on the interactions between land use, ecosystem services and climate change. This is because global change and its different manifestations and consequences impact on land use in most regions of the world. Climate change has been identified as one of the major drivers. However, we do not know enough about how changes in climate actually impact on natural and cultivated landscapes. That is at least partly because it is often difficult to trace perceptible changes in the landscape back to individual factors. We still do not understand enough about how climate change and changes in ecosystems and different forms of land use are connected.

It will become increasingly important to find the right balance between adaptation and climate change mitigation strategies in the future, and to include trade-offs and the effects of linking distant land use systems, such as soya growing in South America and meat and milk production in Germany. Agricultural activities, for example, are not only affected by climate change, they also directly contribute to greenhouse gas emissions – especially CH₄ and N₂O – and therefore to climate change. Furthermore, emissions of NH₃ indirectly interfere with the thermal and material balance of the Earth's atmosphere: NH₃ emissions lead to the formation of secondary aerosols, which could have a significant influence on the radiation balance. They contribute to the eutrophication of natural and near-natural ecosystems and to the indirect emission of N₂O. In the case of natural soils, nitrogen inputs from the atmosphere and, in the case of agricultural soils, inputs connected with cultivation and fertilisation promote mineralisation of organic components and cause CO₂ emissions that – unlike other CO₂ emissions from agriculture – are not “carbon neutral.”

By sequestering CO₂ and serving as carbon sinks, forests and wood play an important role in achieving the federal government's climate targets.

The Forest Climate Fund, jointly managed by BMEL and BMUB, is also used to support research and development projects. One of the main aims of the Fund is to improve the ability of forests to adapt to climate change while in particular maintaining their functions that favour biodiversity and as CO₂ sinks, and safeguarding the potential of forests and wood products to lower CO₂ levels. The projects it finances include ones promoting climate-adapted sustainable forest management and making forest ecosystems less vulnerable to changes in the climate.

The objectives relating to shaping structural change in the forestry industry, adapting to the globalisation of markets, taking precautionary measures for the future and adapting the forestry and timber industry to climate change were taken over from the ERA-NET Sumforest policy that had recently been launched, under which Germany is involved in six research projects within consortia.

As part of the funding activity on sustainable land management that ran between 2009 and 2016, a knowledge base and forward-looking strategies were developed, above all in regions that are particularly relevant to climate change mitigation or are witnessing dramatic changes as a result of land use and climate change. Projects covering interactions between land management, climate change and ecosystem services brought a large number of disciplines together, such as spatial planning, energy provision, agriculture, water management, urban development and forestry, in Germany and Europe but also in Asia, Africa and South America. Involving users and decision-makers in the projects was a crucial element.

At regional level, a transdisciplinary research approach was adopted to build a knowledge base on the complex interrelationships between land use, globalisation, climate change, loss of biodiversity and population growth, to model scenarios of probable future trends and to develop strategies for action strategies. On the Siberian steppe, for example, new soil cultivation technologies were developed which enable humus to be enriched, carbon to be sequestered and properties of the soil improved. These appropriate tillage systems also prevent the erosion of fertile arable land.

The funding measure was part of the Research for Sustainable Development framework programme (FONA³) and contributed to implementation of the German government's sustainability strategy and its climate change targets. BMBF invested a total of EUR 75.9 million in the funding area for work exploring interactions between land management and the climate and ecosystem services between 2009 and 2016.

Another funding activity, on innovative system solutions for sustainable land management, targeted its research work primarily at integrated urban and rural development. Its aims were to enhance regional value added and optimise flows of energy and materials between urban and rural areas. The projects focused on new, sustainable and practicable approaches to land use for regions in Germany facing different challenges. To do this, it was necessary to understand what factors – including climate change and demographic changes – influence land use and what the interdependencies are. Typical questions included how energy, environmental, agricultural and structural policies interact with settlement and transport trends. Altogether, BMBF made EUR 44 million available in this funding area in the period from 2010 to 2016.

The Innovation Groups for Sustainable Land Management funding programme builds on the funding measure outlined above. Its aim is to increasingly pave the way for innovation in sustainability to be put to practical use. The research work is principally targeted at urban-rural relations, the regional energy transition and innovative forms of land use. Several

innovation groups, through their science-in-practice teams, concentrate on implementing the energy transition at regional level and on approaches and technologies for linking renewable energy and land use with the minimum use of resources. BMBF is supporting this funding measure with a total of EUR 30 million in the period from 2014 to 2019.

8.2.2 Modelling and prediction

Since climate modelling is currently the only instrument available for attempting to predict the future climate, it is crucially important to make the modelling results more conclusive.

Climate prediction is based on complex numerical climate models that simulate the global atmosphere and ocean circulation as accurately as possible. The German Climate Computing Centre (DKRZ) offers computing capacity for models such as these to other German research establishments. In 2015/16 a new supercomputer was installed there, one of its purposes being to enable complex scenarios for future global and regional climate models to be calculated efficiently. The supercomputer performs model calculations with a higher resolution, as well as calculation runs using models that are better able to simulate the physical processes in the climate system, known as Earth system models. In this way, uncertainty about how the conditions of life on Earth are likely to develop in the future can be limited somewhat – at least with regard to the climate system.

At DKRZ, with support from BMBF project funding, climate simulations are carried out in the context of the international model intercomparison project CMIP, and thus in preparation for the next IPCC assessment report. The MPI-ESM1 models developed by the Max Planck Institute (MPI) for Meteorology and the chemistry-climate model EMAC are used for this purpose. Simulations using climate and Earth system models make it possible to study climate variability and to detect the climate “signal” in the “noise” of climate variability. The central aim was and remains to detect the anthropogenic “fingerprint” in climate observations since the beginning of the industrial revolution. The available experimental data (from data networks, measuring campaigns, palaeoclimatology and remote sensing) is used to validate the models; conversely, models are used in reconstructing and interpreting the past and present state of the climate. The European Centre for Medium-Range Weather Forecasts (ECMWF), which Germany is part of, currently operates the world’s most comprehensive data assimilation system. It is used in the EU ERA-CLIM project (and successor projects) for global analyses for the 20th century, in which DWD is also involved.

Regional climate modelling, which – by contrast with global climate modelling – also enables predictions to be made about possible climate trends in specific regions, looking at the land surface, for example, has long been an established part of the German research landscape. The COSMO-CLM model is constantly being refined for this purpose and is used for long-term climate predictions and projections. The new global model ICON, which was developed by DWD and the MPI for Meteorology, will allow the resolution of all scales, from global to local, in one model in future – in other words global and regional climate simulations will be performed consistently with a single model.

Various working groups from Germany contribute regional climate projections for Europe and other regions to the international CORDEX project (Coordinated Downscaling Experiment).

More in-depth work has already begun, especially on attempts to further quantify uncertainty and to achieve higher spatial and time resolutions. Another two BMBF funding measures help to quantify uncertainties, improve process understanding and improve climate predictions. ROMIC investigates the influence of solar variability on the climate and

the complex coupling mechanisms between various layers of the atmosphere in respect of anthropogenic changes. The strategic objective of the PalMod initiative is to evaluate future climate projections for this century by simulating the last glacial-interglacial cycle using complex Earth system models.

Research using decade-long time scales is being carried out within BMBF's MiKlip (decadal climate prediction) funding priority. It aims to develop a model system – based on the Earth system model (MPI-ESM) used at the Max Planck Institute for Meteorology in Hamburg (MPI-M) – to forecast the changes in climate and associated extreme weather events that can be expected on a time scale of up to 10 years (see section 8.2.3). The forecasting system takes into account both anthropogenically induced climate changes and natural variations in climate on a regional and global scale. The climate predictions obtained in this way and a comprehensive assessment of forecast quality will create the framework needed to improve the capacity of industry and society to adapt to future climate fluctuations.

To reduce uncertainties, further improvements are being made to the mathematical methods used in the models and to the description of the sub-scale processes (parameterisation) in the climate models. The latter is particularly necessary in view of the steady decrease in grid width in the models. Processes that have previously been neglected – such as the carbon cycle, dynamic vegetation and dynamic trends in sea ice – are also being included in the model.

HD(CP)² is a funding initiative looking at cloud and precipitation processes and their implications for climate prediction, investigating the climate using finer temporal and spatial scales. Its aim is to develop a climate model – based on the global ICON model – that can be used to physically model cloud formation processes, the development of precipitation and precipitation processes. This will advance how we deal with climate change and in particular with adaptation to the extreme weather associated with it. A sound scientific basis created in this way will make it possible to identify more reliable measures for mitigating climate change, estimating its effects and drawing the necessary conclusions for mitigation and adaptation.

CLOUD is another funding measure that is designed to clarify the physical connections between cloud formation and the effects on the climate. The CLOUD project, which is being conducted at CERN (particle accelerator, European Organization for Nuclear Research), aims to provide a well-founded and quantitative understanding of the possible links between galactic cosmic rays (GCRs) and the Earth's climate. The CLOUD consortium is studying the influence of GCRs on atmospheric chemistry, aerosol particles and clouds, in order to identify the possible role the Sun plays in climate change.

MACC is a project that has now ended which was funded by the European Commission and carried out at ECMWF with the involvement of numerous German research institutions. Its work included developing a global analysis and prediction system for key greenhouse gases and aerosols. The system, which was developed for operational use, can continuously determine the global distribution of trace gases and aerosols that have an impact on the climate, as well as their sources and sinks.

The available experimental data (from data networks, measuring campaigns, palaeoclimatology and remote sensing) is used to validate the models. Conversely, models are used in reconstructing and interpreting the past and present state of the climate. For example, a project being conducted at HERZ (Hans Ertel Centre for Weather Research) is working on a regional re-analysis for Europe.

8.2.3 Climate impact research

Climate impact research, which investigates the interactions between changes to the climate on the one hand and natural systems and human society (socioeconomic systems) on the other, establishes the scientific basis for adaptation research. It utilises approaches and methods from research on climate systems and climate impact. Predictions of the range of climatic changes that might be expected in the future – both spatially and in terms of time – and predictions about their likelihood form an important basis for adaptation research and for assessing the risks associated with climate change and therefore the benefits of mitigation activities. This provides the foundation for robust analyses of specific climate change adaptation measures for regions, sectors, businesses or national economies.

Many of the German government's research funding activities on climate change and adaptation are financed as part of the Federal Ministry of Education and Research (BMBF) framework programme entitled Research for Sustainable Development (FONA³). Other ministries also have programmes conducting research into adaptation and trialling adaptation measures on a pilot basis; for example the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) had a priority programme on adaptation to the impacts of climate change as part of its Environmental Research Plan, and the ImmoKlima and StadtKlima research fields within its experimental housing and urban development programme ExWoSt. The Federal Ministry of Transport and Digital Infrastructure (BMVI) brought together a large section of the sectoral research activities on adaptation within the KLIWAS programme (Impacts of Climate Change on Waterways and Navigation in Germany – Searching for Adaptation Options). BMVI also funded the KlimaMORO Spatial Development Strategies for Climate Change model projects, for example.

Limited-term research and development projects are also assigned as part of competitive procedures. Large-scale collaborative projects for regions or cities have received funding in the form of earmarked contributions for projects within funding programmes or specific sectoral programmes, for example from BMBF.

The federal government's activities are pooled and coordinated within the Interministerial Working Group on Adaptation to Climate Change. The coordination resulted in the German Strategy for Adaptation to Climate Change (DAS) and its regular updates, supplemented by action plans (see Chapter 7).

BMBF's new funding programme, Urban Climate Under Change, is intended to produce a scientifically based, practicable set of instruments for addressing the problems associated with climatic conditions now and in the future. The urban climate model that it develops will simulate atmospheric processes at building-level resolution and place them in the context of microclimatic interactions. This will enable interdisciplinary analyses to be conducted for assessment purposes and measures for improving the urban climate to be planned.

The Potsdam Institute for Climate Impact Research (PIK) works on relevant climate impact research issues. Researchers from the natural and social sciences collaborate on an interdisciplinary basis to improve the scientific foundation for decision-making in politics, business and civil society. The main methodological approaches used at PIK are system and scenario analyses, quantitative and qualitative modelling, computer simulation and data integration. PIK is involved in numerous national and international collaborations.

In addition, BMBF and the state of Brandenburg founded the Potsdam Institute for Advanced Sustainability Studies e.V. (IASS) in 2009. The institute takes an integrated

approach to transdisciplinary and international research into climate change, the components of the Earth system and sustainability. Its aim is to translate scientific knowledge into an integrated view of sustainability, centred around interdisciplinary and transdisciplinary approaches. The institute is involved in cutting-edge research and is supported by members of the Alliance of Science Organisations in Germany and its institutions. One of the institute's key tasks is to stimulate strategic dialogue with representatives from business, politics, society and the arts and to communicate scientific knowledge to society.

Within the joint Agricultural Extreme Weather and Risk Management Possibilities research project, BMEL supported work on estimating changes to the occurrence of extreme weather triggered by climate change and their potential impact on German agriculture and forestry. The Thünen Institute, Julius Kühn Institute, Deutscher Wetterdienst (German Meteorological Service, DWD) and other institutions addressed research questions dealing with the current and future relevance of extreme weather, including issues of regional concern, crop-specific risk of damage from extreme weather and various options for adaptation in order to provide information for individual operational planning and for private and public risk management in agriculture and forestry.

8.2.3.1 Improving climate change impact assessments and vulnerability identification

In line with the agreement in Action Plan I of the German Strategy for Adaptation to Climate Change, a cross-sectoral analysis of Germany's vulnerability to climate change was produced for Germany for the first time in 2015 (see section 7.4, p. 191 ff). This entailed the development, on behalf of the federal government, of analytical methodology covering multiple areas of activity. A screening process was used to identify regions and systems that are particularly threatened by climate change, throughout Germany and across all fields of action. The standardised procedure and uniform criteria form the basis for a targeted adaptation policy by providing pointers to the need for further action.

On the basis of the vulnerability analysis, the Interministerial Working Group on Adaptation to Climate Change of the German Federal Government published its Guidelines for Climate Impact and Vulnerability Assessments in 2017. The aim of the guidelines is to produce comparable research results from sectoral and cross-sectoral climate impact and vulnerability analyses at federal and state (Land) level.

The available vulnerability analysis did not allow all aspects needed to determine and describe vulnerability to be addressed. It is therefore necessary to review the findings, the data used and the methodological approach at regular intervals. In the Progress Report on DAS (2015) it was agreed that a vulnerability analysis should be produced every six years, starting in 2021.

8.2.3.2 Ecosystems and biodiversity

Ecosystems and biodiversity are severely affected by the impact of climate change and at the same time play a key role in the global carbon cycle.

Project-specific funding has been allocated to various BMBF programmes, including the Biodiversity and Global Change (BIOLOG) and Biosphere Research – Integrative and Application-Oriented Model Projects (BioTeam). A current funding priority is Sustainable Land Management – Module A: Interactions between Land Management, Climate Change and Ecosystem Services. The aim here is to support regions that are particularly severely affected in developing sustainable land management systems. Projects are also being funded within ERA-Net BiodivERsA.

Institutional funding for ecosystem and biodiversity research studying the effects of climate change is given to several institutes within the Helmholtz Association of German Research Centres (HGF), the Max Planck Society (MPG), the Fraunhofer-Gesellschaft (FhG) and the Leibniz Association (WGL). In the Helmholtz Association, this research is being carried out in the Earth and Environment research field, in three programmes: Geosystem: the Changing Earth; Marine, Coastal and Polar Systems; and Terrestrial Environment. The Leibniz Association carries out research on biodiversity, oceans and lakes, and environment and energy.

In 2016 the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) and the University of Oldenburg joined forces to set up the Helmholtz Institute for Functional Marine Biodiversity at the University of Oldenburg (HIFMB). The Helmholtz Institute will be located on the campus of the Carl von Ossietzky University of Oldenburg and will further consolidate the partnership between the Helmholtz Association and the university.

The German research fleet researches biodiversity and changes to biodiversity in the oceans around the world.

Other important institutions in Germany that work on the interactions between climate change and ecosystems include:

- Bayreuth Center of Ecology and Environmental Research (BayCEER)
- Biodiversity and Climate Research Centre, Frankfurt (BIK-F)
- German Centre for Integrative Biodiversity Research (iDiv)
- Ecology Centre, Kiel (ÖZK)
- Johann Heinrich von Thünen Institute, Federal Research Institute for Rural Areas, Forestry and Fisheries (TI), especially in the following TI institutes: Biodiversity, Forest Ecosystems, International Forestry and Forest Economics, Fisheries Ecology, Organic Farming and Climate-Smart Agriculture
- Julius Kühn Institute, Federal Research Centre for Cultivated Plants

8.2.3.3 Coastal regions

Under FONAS³, BMBF funds interdisciplinary and transdisciplinary research into the conservation of coastal ecosystems and their ecosystem services, integrated coastal protection and the sustainable management of coastal zones. Questions surrounding the use of coastal zones are examined in connection with natural and anthropogenic interactions and their impacts on ecosystems. Other priority areas include the preparation of risk-based adaptation strategies and the development of prognostic models of the impacts of climate change and changed conditions of use.

Since 2012, the Coastal Research North Sea/Baltic Sea (KüNO) consortium (<https://deutsche-kuestenforschung.de>) has been working to establish the scientific base for ecosystem-oriented management of coastal resources. Currently there are 12 collaborative projects receiving funding, which focus their research on these areas:

- Conserving the ecosystem services provided by German coastal systems in the light of changes in use and climate change
- Improving the ability to predict/estimate the effects of global change on coastal ecosystems

- Research to facilitate evidence-based implementation of integrated marine policy at national and EU level
- Identification of climate-related security risks, further development of design procedures and infrastructures in coastal protection and the development of appropriate planning and decision-making tools, with the aim of achieving sustainable coastal management

In light of the fact that climate- and weather-related natural hazards require the Länder along the north German coast to invest extra effort in coastal protection, BMBF has been constantly involved in the German Coastal Engineering Research Council (KFKI) for several decades. In this research programme, BMBF cooperates closely with the Länder in funding research projects that are explicitly focused on the engineering aspects of coastal and flood protection, coastal drainage and the construction and maintenance of coastal protection structures, waterways and ports.

In addition to its activities in the Coastal Research North Sea/Baltic Sea (KüNO) consortium and national activities within KFKI, BMBF is engaged in the multinational BONUS research funding network (Article 185 initiative, Joint Baltic Sea Research and Development Programme BONUS), under which the following priority areas have been funded as part of joint calls for proposals from the Baltic Sea states since 2012:

- Understanding the Baltic Sea ecosystem structure and functioning
- Investigation of the interactions of the Baltic Sea with coastal regions and catchment areas (coastal zone management)
- Sustainable use of marine and coastal goods and services of the Baltic Sea region
- Identification of future social challenges facing the Baltic Sea region and the development of appropriate solutions
- Development and testing of innovative in-situ remote sensing techniques and of marine and maritime information and communication services for the Baltic Sea region

On the basis of the second Sino-German government consultations in August 2012, BMBF issued a bilateral call for proposals in June 2013 which led to the investigation of long-term changes to the climate and anthropogenic influences on coral reefs, mangroves and seagrass beds in coastal waters of the South China Sea in three joint projects, SINOFLUX, CLIFLUX and ECOLOC, since 2014. The densely populated Chinese province of Shandong has a 3,000-kilometre coastline; German researchers have cooperated with Chinese science centres to integrate various climate trend scenarios for this region into a decision support system that is meant to help in future to significantly reduce the damage that could be caused by the forecast rise in sea level and the anticipated increase in frequency of storm events.

Germany's activities in coastal waters research are supporting a number of international research programmes: the World Climate Research Programme (WCRP), the Land-Ocean Interactions in Coastal Zones (LOICZ) project within the International Geosphere-Biosphere Programme (IGBP) and UN marine policy (including the 2030 Agenda and SDG 14).

8.2.4 Socioeconomic research on the causes and effects of climate change

8.2.4.1 Cross-cutting research on renewable energy and transformation of the energy system

Since March 2013, BMBF has funded under its Social-Ecological Research (SÖF) programme around 30 projects that monitor and support the environmentally sound and socially acceptable transition of the energy system towards renewable energy. The total amount of funding provided is roughly EUR 30 million. The measure focuses on three research priorities:

- Presenting and evaluating options for developing the energy system;
- Analysing the conditions needed for society to accept the transition and promoting active public participation;
- Governance of the transition process.

Social aspects are extremely important as the energy transition takes shape, a transition that can only succeed if it reflects the needs and expectations of the population, industry, commerce and local authorities – including questions of participation and justice – and takes account of requirements associated with a free market economy.

This is the starting point for the Environmentally and Socially Compatible Transformation of the Energy System funding initiative. One of its research priorities is to describe and evaluate options for developing the energy system, including economic scenarios. Another key approach involves analysing the conditions for society to accept the transition and promoting public participation. The regulatory framework (governance) of transition processes, including economic instruments, is equally important.

Most of the planned projects are designed to cut across the various priority areas and look – at least incidentally – at different forms of civic participation. About a third of the projects explore all three priority research areas. For example, they work in conjunction with local authorities to test which forms of informal participation process can help to make planning permission procedures for major infrastructure projects – such as on local storage of electricity from renewable energy – run more smoothly, more quickly and in a way that is on solid legal ground. They also factor the energy consumption and production behaviour of private households into conventional energy management models. New roles for consumer groups – as investors, for example – and for energy suppliers – as managers of distributed energy systems – are also being analysed. Working in collaboration with policymakers, business and civil society, academics are trying to identify incentives that could motivate people to change their behaviour and move towards a low-carbon lifestyle. A number of projects are concerned with the idea of social justice, such as how to take account of low-income sectors of the population. Possibilities for decentralised financing of technical innovations are also being analysed, and ways of supporting key stakeholders locally are being sought.

This funding measure aims to play a role in managing the move to a new energy era at local level and to propose solutions that are both academically well founded and relevant to practical action.

8.2.4.2 Socio-environmental research

The primary objective of BMBF's Social-Ecological Research funding priority is to work with practitioners to develop strategies and options for actions to implement the national

sustainability strategy. It deals with problems that arise in the relationships between people and their natural and social environment. It investigates the options for shaping these relationships, taking an interdisciplinary approach. The programme attaches particular importance to giving equal weight to insights about the social and scientific dimensions of sustainability.

Climate-relevant socio-ecological research takes place as part of the funding initiative concerned with the environmentally sound and socially acceptable transition of the energy system (see section 8.2.4.1) and in:

- Projects within the focal areas of Societal Transformation in the Face of Climate Change and Sustainable Transformation of Urban Areas
- Projects carried out by junior socio-ecological research groups

The Societal Transformation in the Face of Climate Change funding measure is part of the call for projects within topic 1 of the same name under the European Joint Programming Initiative JPI Climate. Six European joint projects have been funded under the JPI Initiative since November 2014. The aim is to use interdisciplinary and transdisciplinary projects to gain new insights into climate-related societal challenges and transformation processes and to develop strategies for solutions. German institutions are involved in three projects, which receive about EUR 1.3 million in funding and deal with the following issues:

- Self-organisation by civil society stakeholders to counter climate change in urban areas
- Reducing greenhouse gas emissions in households
- Analysing the public perception of climate change, attitudes to various energy options and the related assessment of Germany's energy transition

The Sustainable Transformation of Urban Areas funding measure has supported 23 joint interdisciplinary and transdisciplinary projects on society-related matters with about EUR 22 million of funding since June 2016. They draw up proposals for sustainable transformation processes in urban areas and work with practitioners to road test them. Of these projects, 11 (with a funding volume of around EUR 11 million) deal explicitly with energy- and climate-policy issues. These include low-carbon living and mobility close to the home, vulnerability analyses and risk assessments in connection with climate change mitigation and adaptation, public participation in climate-smart urban redevelopment, and the use of networking across local authorities to activate potential for climate action.

In the context of socio-ecological research, a junior research group has received funding of EUR 0.7 million since 2016 for work directly related to energy and climate. It is investigating the link between environmental change – especially climate change – and migration. Changing environmental conditions, for example in the form of droughts and severe weather events as a consequence of climate change, can contribute to emigration flows. Immigration, likewise, can cause new environmental problems, such as over-exploitation of natural resources. The aim is to develop an instrument for political decision-makers that enables migration and the sustainable use of resources to be systematically integrated into climate adaptation policies and programmes.

8.2.4.3 Economic aspects of climate change

As climate change accelerates, the debate about its economic dimensions is intensifying. Practicable approaches are sought that can be used to reliably estimate the costs, risks and opportunities associated with climate change mitigation and adaptation and to design

practical and efficient solutions. Climate economics research is greatly significant in this connection.

Climate economics research studies things such as the effects of different emissions pathways, evaluates their economic, social, environmental and technological implications, and tries to find appropriate economic steering instruments and governance models. Important questions it addresses are: what costs must we expect for climate change mitigation and adaptation? Which climate change instruments make economic sense? On what principles can efficient, effective and equitable climate change agreements be negotiated?

In the Economics of Climate Change funding priority, BMBF provided a total of EUR 16 million for 27 projects during the first funding phase (2011–2016). A call for proposals for a second funding phase was published in October 2016. The main topics for priority funding in the second phase are:

- Climate change mitigation and transformation: decarbonisation – competitiveness – quality of life
- Climate change mitigation: instruments and policies under COP21
- Dealing with climate risks
- International climate policy

Issues relating to financial markets and financial market actors are addressed as a cross-cutting issue. UBA is conducting an in-depth economic analysis of individual policy instruments and measures for adaptation to climate change in ongoing projects. The intention is that the potential damage from climate change should be monetised – where possible – and economic justification should be provided for an optimum policy mix of adaptation measures.

8.2.5 Research and development on reduction and adaptation options, including technologies

8.2.5.1 Energy research

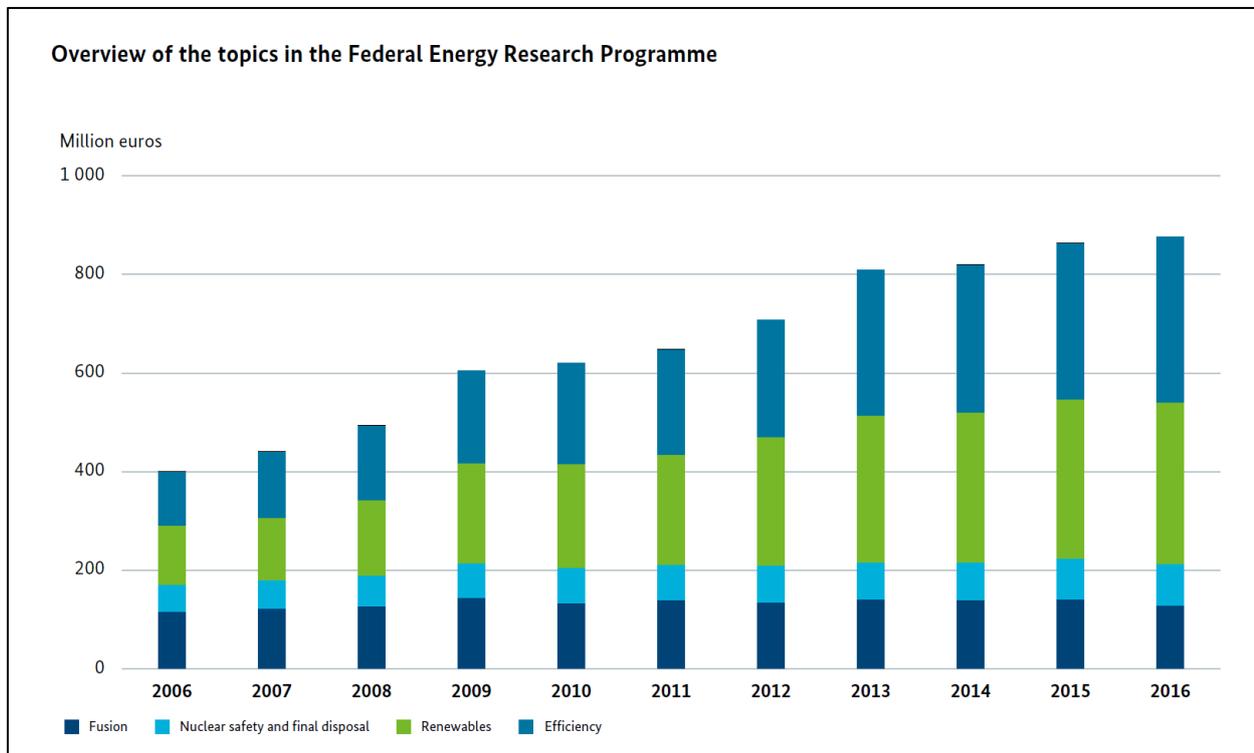


Figure 38: Overview of topics covered by the German government's Energy Research Programme¹⁹⁸

The lead ministry for energy research, the Federal Ministry for Economic Affairs and Energy (BMWi), launched a consultation process to prepare for the 7th Energy Research Programme at the end of 2016 with the aim of systematically realigning funding policy with the objectives and requirements of the energy transition and building on the progress already achieved.

International cooperation is of key importance to Germany, as its economy is geared to global markets. In the context of international cooperation, therefore, the German government is participating in Mission Innovation, a large-scale international initiative to promote research and innovation on clean energy technologies. It came into being in November 2015 during the COP21 Climate Conference in Paris as a grouping of 22 states, including the USA, China, India, Brazil, the UK, Japan, France and Germany, plus the European Union. As part of the initiative the countries involved are aiming to double their expenditure on research and innovation in the energy sector within five years and intensify international collaboration within the group.

Germany has good basic research, an efficient scientific/technical infrastructure and outstanding industrial energy research. The above-average involvement of German partners in the EU Research Framework Programme and the fact that international auditors give the Helmholtz Association's research programmes ratings of good to excellent testifies to this, as does the very good result of the evaluation of the German Biomass Research

¹⁹⁸ Federal Ministry for Economic Affairs and Energy (2017). Report of the Federal Government on Energy Research 2017.

Centre (DBFZ) by the German Council of Science and Humanities (Wissenschaftsrat – WR).

Two complementary instruments, which also interact, are used to support research and development: project funding and institutional funding.

The federal government has further broadened its commitment to energy research as a key element to the long-term success of the energy transition, and in 2016 continued the positive trend in funding growth from previous years. Altogether around EUR 875.98 million of federal funding was invested in energy research in 2016. The figure for 2015 was EUR 862.73 million. The thematic focus of funding for research and development was placed on renewable energy and energy efficiency, which together accounted for about three quarters of all deployed funds.

The figures on project funding can be found in the annual Report of the Federal Government on Energy Research and on the EnArgus website (www.enargus.de). In total, the government has invested around EUR 12 billion in research and development since the start of the energy research programmes in 1977.

In addition to project funding, the German government also pursues dialogue with energy research stakeholders so as to ensure the practical orientation of research and development activities and accelerate the transfer from laboratory into practice. The energy transition Research and Innovation Platform is one of BMWi's five energy transition platforms and acts as a strategic advisory group on overarching issues of energy research policy. The platform provides the foundation for an intensive process of dialogue and participation between all stakeholders in the innovation chain. With the involvement of all the participating ministries, BMBF brings together high-ranking stakeholders from politics, science, industry and civil society in the Energy Transition Research Forum. Together they discuss and assess the science-based options for action that the Energy Systems of the Future academy project has prepared. The principal outcome of the work produced by the Energy Transition Research Forum is the four Kopernikus projects, which are currently addressing key themes of the energy transition.

International cooperation is an important building block for successful innovations from research and development. At the 2016 G7 Summit in Japan, the participating states once again confirmed the significance of energy research in mastering global challenges presented by the transformation of energy systems and securing affordable energy supplies. Cooperation mainly takes place within the European Union (EU) and the International Energy Agency (IEA), and via individual bilateral or multilateral initiatives.

8.2.5.2 Key technologies and cross-cutting technologies for climate change mitigation

Research and development in the field of key technologies paves the way for improvements to climate change mitigation in numerous applications. For example, new high-tech materials make vehicles lighter, batteries more powerful and buildings more environmentally sound. Developments in microsystems and ICT have improved the control and therefore the energy efficiency of production facilities and energy installations. The following key technologies and cross-cutting technologies are funded through programmes and measures run by BMBF and other ministries:

- Photonics (Photonics Research Germany funding programme)
- Production technologies (such as Resource-Efficient Production funding priority)
- Materials technologies (WING – Materials Innovations for Industry and Society)

- Biotechnology (Biotechnology framework programme)
- Nanotechnologies (Action Plan Nanotechnology 2015)
- Microelectronics (Microelectronics from Germany – Driver of Innovation for the Digital Economy framework programme)
- IT security (Self-Determined and Secure in the Digital World framework programme)
- Communication systems
- Data science, information technologies
- Innovative services (Innovations for Tomorrow’s Production, Services and Work umbrella programme)
- Federal Ministry of Food and Agriculture's (BMEL) Innovation Programme
 - Big data in agriculture
 - Innovations in animal husbandry, plant production and soil management as a contribution to climate change mitigation in line with the Paris Agreement – COP21
 - Promotion of innovations for safe, resource-saving and sustainable food production

Innovation alliances and funding for traditional collaborative projects with partners from research and industry are important instruments in this area.

8.2.5.3 Research on renewable energy

Almost one third of Germany’s electricity is already generated from renewable energy. In the heat and transport sectors, however, there is still urgent need for progress. In 2016 the federal government made EUR 875.98 million available to fund energy research. Funding has thus more than doubled since 2006. Two key pillars, energy efficiency and renewable energy, took up about three quarters of the funds. Expenditure on research into renewable energy in 2016 amounted to roughly EUR 329 million – an all-time high.

Funding topic	Disbursements in million euros										
	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Energy efficiency	110.34	133.95	151.55	189.31	206.13	215.14	239.06	296.64	300.80	317.26	336.09
Renewable energies	120.23	126.47	152.86	202.01	210.61	221.91	258.85	298.10	303.30	323.33	328.82
Nuclear safety and waste disposal	54.33	57.58	62.59	70.41	71.93	73.03	74.74	75.62	76.95	82.92	84.44
Fusion	114.41	121.52	125.58	142.65	131.03	137.44	133.10	138.72	138.14	139.22	126.63
Total	399.31	439.52	492.58	604.37	619.71	647.52	705.75	809.09	819.20	862.73	875.98

Table 24: Overview of the disbursement of funding to individual funding areas in the German government’s 6th Energy Research Programme¹⁹⁹

Research in photovoltaics, wind energy and bioenergy is particularly important. New funding of over EUR 230 million was approved in these three fields in 2016.

¹⁹⁹ Federal Ministry for Economic Affairs and Energy (2017c).

In addition to furthering the development of highly application-oriented innovations, energy research promotes technologies that are on the verge of going into production on an industrial scale or are on the way to it. Within the photovoltaics field, organic photovoltaics are becoming increasingly significant, for example, as are – in the laboratory – perovskite-based photovoltaics. One crucial challenge for wind energy is lengthening the useful life of wind turbines on the basis of innovative material properties. Research funding in the field of bioenergy covers the production of chemical fuels and base chemicals for the chemical industry, and industrial biomass production using algae.

BMEL supports research and development in bioenergy mainly with funds from the Special Energy and Climate Fund (EKF). The projects are managed by FNR (Fachagentur Nachwachsende Rohstoffe e.V. – Agency for Renewable Resources), acting as BMEL's project administration agency. Since 2015, research funding in the bioenergy sector from EKF funds has focused on the following priorities:

- Determining and developing technologies and systems for producing and utilising bioenergy with the objective of further improving greenhouse gas balances in the principal areas of application, namely electricity, heat and fuels
- Optimising the integration of bioenergy into regional and supra-regional energy (infrastructure) systems (heat, electricity, mobility) with the objective of improving system stability and energy efficiency

As of 31 March 2017, 194 projects were receiving funding, totalling about EUR 83 million.

The majority of the funding is taken up by projects to improve greenhouse gas balances in the use of bioenergy. The range of projects includes those on biomass supply, conversion processes and biomass use in the electricity, heating/cooling and transport sectors. Along with emissions avoidance, the focus is also on improving energy efficiency.

The second funding priority concerns research into the possibilities of bioenergy as a vital element in systems dominated by renewable energy sources. The main emphasis in this case is on topics such as flexible, demand-oriented energy generation, innovative storage solutions and coupling of energy carriers and sectors.

Research projects on the utilisation of biomass for energy are also funded under the Renewable Resources funding programme. Issues surrounding energy recovery from biogenic residues and wastes, renewable heating energy and energy from aquatic systems have an important part to play here.

System-oriented energy research has come more sharply into focus in recent years. This includes system analyses, for example, and aspects of social participation in the energy transition, as well as matters relating to sector coupling. A new systemic priority was set in 2016 in the form of the Kopernikus projects. These have a term of ten years, involve science/academia, business and civil society, and build a bridge from development through to application on a large scale. The four projects emerged from a wide-ranging agenda process and examine the key themes of Power-To-X, power grids, industrial processes and the interaction between these sectors in the social context. Climate-relevant CO₂ savings effects are expected to be achieved with the Carbon2Chem project. Utilising the flue gases from steel production could save up to 20 million tonnes of annual CO₂ emissions in Germany alone. To attain the ambitious goals of this ten-year research project, leading German companies in the chemical, steel, energy and automotive sectors joined forces with universities and research institutions. Carbon2Chem therefore promotes broad-based cooperation between key national industries and the institutional research sector.

In the context of the energy transition, the development and improvement of materials for use in the generation and use of energy is a matter of key importance, forming the basis for innovative energy technologies. The purpose of these materials is to optimise the efficiency of energy generation and pave the way for applications for renewable energy sources, for instance by enabling load flexibility or utilising renewable fuels. Increasing the efficiency of energy use is also important, for example by using innovative building insulation materials or energy storage systems. BMBF successfully initiated the materials research for the energy transition funding priority as early as 2013 for this reason. The funding initiative specifically aims to establish strategic links between innovative solutions for existing structures and ideas for questions relating to materials. The range of topics in this funding initiative, which is oriented towards basic research, is open to all technologies and extends across all areas of the energy sector. Funding to date has focused on photovoltaics, wind turbines, power plant technologies, energy storage systems, insulating materials, fuel cells and electrolysis. The funding initiative thus embraces fundamental projects that prepare the material basis for a multiplicity of future developments in the field of technologies for energy generation and energy use for the energy transition. Seven junior research groups receive funding under the initiative as part of the scheme to support the next generation of scientists.

The Karlsruhe Institute of Technology (KIT) is cooperating with the German Aerospace Center (DLR) and the Forschungszentrum Jülich (FZJ) to set up a plant network for research into energy systems in its Energy Lab 2.0 project. Components for generating, converting and storing electrical, thermal and chemical energy are interlinked with each other, forming a real-life experimental facility with existing consumers. Wind farms, geothermal facilities, electrolysis systems, conventional power plants and industrial consumers are integrated using information technology. This enables application-oriented research to be conducted on the various energy grids (electricity, heat, gas, fuels) within an integrated smart energy system. The aim of Energy Lab 2.0 is to develop improvements to the efficiency and flexibility of the system as a whole, thus contributing to the stabilisation of energy grids.

8.2.5.4 Mitigation in industrial process and products – increasing resource efficiency and the use of CO₂

Under BMBF's Research for Sustainable Development framework programme (FONA³), the flagship Green Economy initiative pursues the target of transitioning to an internationally competitive, environmentally sound and socially equitable economy. Application-related, implementation-oriented research, conducted in conjunction with businesses and other stakeholders, is meant to lead to the development of sustainable processes and products and their introduction into practical use. One of the priorities of preventive research in FONA³ is the intelligent and sparing use of resources. This includes boosting resource efficiency by saving raw materials and closing cycles, recovering raw materials by recycling and urban mining, and substituting fossil raw materials with alternatives that are less damaging to the environment and more climate-friendly (using carbon dioxide as a raw material, for example). Resource efficiency and energy efficiency are closely linked; in other words, reduced use of primary raw materials generally yields considerable savings in energy required for the production and processing of the raw materials, and consequently also lowers greenhouse gas emissions. Resource efficiency thus has a significant direct and indirect impact on climate change mitigation.

The BMBF funding measure r³ – Innovative Technologies for Resource Efficiency – Strategic Metals and Minerals, which came to an end in 2016, devised specific solutions for

saving and recovering strategically important raw materials through substitution, recycling and urban mining. Altogether it funded 28 collaborative projects, providing around EUR 30 million, with a further EUR 12 million added by business.

One of the priorities of the ongoing BMBF funding measure r⁴ – Innovative Technologies for Resource Efficiency – Research on the Supply of Raw Materials of Strategic Economic Importance, alongside exploration and the efficient extraction of primary raw materials, is the recovery of processing and production residues and recycling of old products. The actual recycling rates for many strategically important raw materials (such as alloy elements, rare earths and metals used in electronics) are currently below 1 %. There is a lack of suitable return and recycling systems; these are the subject of research. BMBF is providing total funding of approximately EUR 50 million for 40 collaborative projects in connection with r⁴.

BMBF's SME Innovative funding initiative was previously described in the Sixth National Communication, and continued unchanged during the reporting period of the Seventh National Communication.

Carbon dioxide can also be used as a raw material. If it is used to replace oil-based raw materials, a two-fold saving in CO₂ is obtained: firstly by the direct use of CO₂, and secondly by the substitution of fossil raw materials that have an unfavourable carbon footprint. BMBF supported research and development in this area with about EUR 100 million of funding in the period from 2009 to 2016 (Technologies for Sustainability and Climate Protection – Chemical Processes and Use of CO₂ funding measure), placing Germany at the forefront of this technological field. Under the follow-up funding measure, CO₂Plus – Utilisation of CO₂ to Broaden the Raw Material Base, 13 projects will receive funding of about EUR 17.5 million in the period from September 2016 to the end of 2019. They can be categorised into three topic areas:

- Utilisation of CO₂ as a material to produce base chemicals or polymers
- Integration of renewable energy into the direct electrochemical or photochemical conversion of CO₂ into useful chemicals
- Separation of CO₂ from process waste gases, biogas and air

The funding measure r+Impulse – Impulses for Industrial Resource Efficiency is designed to speed up the translation into practice of promising research results from the field of resource efficiency and the use of CO₂ as a material. The purpose of the measure is to support new, sustainable technologies on their way to market. It therefore funds projects that aim to achieve a high degree of technological maturity, for example by upscaling or by building a pilot plant, under industrial leadership. Since the beginning of 2016 about EUR 20 million of federal funding has been provided for 17 joint projects, and two further submission dates are planned, in 2017 and 2018.

Since 2016 the Carbon2Chem project has been researching how to turn steel mill gases from steel production into valuable preliminary products for fuels, plastics or fertiliser. The aim is that Carbon2Chem should convert 20 million tonnes of annual CO₂ emissions in Germany's steel sector into economically useful products (see section 8.2.5.3).

8.2.5.5 Climate change mitigation in the buildings sector

The Energy in Buildings and Neighbourhoods research network was established in 2014 to offer a "forum for representatives of the business and scientific communities and important multipliers to intensify exchanges at the interfaces between research on the one hand and

practitioners and policymakers on the other” (Forschungsnetzwerk Energie 2015). Expert recommendations on the need for research and on the transfer of results which were developed by members of the network served as the basis for the Solar Building Design/Energy-Efficient Cities interministerial research initiative (Federal Ministry of Economic Affairs and Energy/Federal Ministry of Education and Research), which was launched in April 2016. The initial projects were launched in spring 2017.

The latest call for proposals, EnEff.Gebäude:2050, was also launched in April and is intended to close the gap between funding research and funding more broad-based activities. The goal of this model project is to encourage many different players in the buildings sector to take action and help overcome barriers to make existing buildings nearly climate-neutral.

8.2.5.6 Mobility and climate change mitigation

The mobility sector has a key role to play in climate change mitigation, especially as in contrast with all the other sectors very little progress has been made in reducing CO₂ emissions in this sector in Germany in recent years. The German government is therefore pooling its efforts in the field of electric mobility, in which BMWi, BMBF, BMVI and BMUB are all involved. The main element of these efforts remains the National Platform for Electric Mobility (NPE), an association of automobile manufacturers, suppliers, energy suppliers and ICT companies working in this field, which advises the government on shaping the relevant programmes. Further strategies for an alternative energy supply in the transport sector are being explored within the National Hydrogen and Fuel Cell Technology Innovation Programme. Various funding measures on autonomous and networked electric driving are making other vital contributions to research. BMWi is pooling its activities in this field in the New Vehicle and System Technologies programme. BMVI’s research programme on automation and networking in road transport also supports projects whose aims include the reduction of emissions.

The Mobility2Grid project funded by BMBF is specifically examining sector coupling between mobility and renewable energy. A crucial feature of this is openness to technological alternatives. BMBF is therefore also intending to push for greater progress in research into synthetic fuels that can be used to store surplus renewable energy.

Intelligent sector coupling through closer technological linking of the energy sector and transport sector in the context of innovation policy is also the focus of BMWi’s cross-programme research initiative Energy Transition in the Transport Sector: Sector Coupling Through the Use of Electricity-Based Fuels. It was launched in the first quarter of 2017, and concentrates on cross-sectoral approaches to alternative electricity-based fuels, integrating new technologies into the energy sector and researching and developing special applications in maritime systems.

BMEL’s funding for research into the efficient use of fuel in agriculture also makes an important contribution to climate change mitigation. Under its renewable resources funding programme, BMEL funds research projects aimed at developing and validating new, innovative application technology for advanced biogenic fuels, as well as optimising existing technology.

Urban areas are an important focus of mobility research. BMVI is investing EUR 4 million in research into urban transport as part of its FoPS research programme. In addition, in 2017 BMBF is engaging in an agenda process on sustainable urban mobility to identify research potential in this field. It hopes that urban development, user perspectives and technological

opportunities will be brought together to develop a better systemic understanding of urban mobility.

8.2.5.7 Applied adaptation research

In this field the German government funds scientific studies on adaptation to climate change and publicises the research findings. In many cases, federal government agencies and experts – including those from Länder agencies and the scientific community – share information. The federal government's research activities are combined in the Adaptation Action Plan, which was last updated in 2015 (see Chapter 7).

BMBF contributes to mastering the regional challenges of climate change by means of transdisciplinary and needs-oriented research within its funding measure on climate resilience through action in cities and regions, part of the flagship initiative City of the Future under the FONAS³ programme. Starting out from specific climate adaptation needs, innovative measures and options for action are developed and tested that are designed to strengthen adaptation capacity but at the same time, in pursuit of multiple benefit, play a part in climate change mitigation and/or other fields of activity in sustainable development. Further methodological developments in determining adaptation capacity and adaptation progress are also expected.

Since mid-2011, BMBF has been financing cross-sectoral projects on the economics of climate change, which – from a primarily national economic perspective – formulate action-oriented adaptation models and activities and approaches to estimating the costs, risks and opportunities associated with low-carbon growth and development models for German society. Expertise from the social sciences and humanities has also been incorporated into the discourse: BMBF's interdisciplinary funding initiative on the social dimensions of climate change mitigation and climate change has helped to enhance competence in the social sciences and the humanities in the field of climate research by increasing understanding of the social causes and effects of climate change and supporting the design of climate change mitigation and adaptation policies.

BMBF is planning to conduct research on regional adaptation capacity and need for adaptation within a funding measure on regional information about climate change. Working in specific model regions, the plan is to assess vulnerabilities, risks and need for action at the regional and urban level, carry out impact analyses of implemented adaptation measures and perform an integrated evaluation on the basis of coupled economic and climate models.

It is becoming increasingly important that the design of infrastructure is climate-robust - especially because of its susceptibility to extreme climate events, its key supply role in the economy and society, and the fact that it has to be planned a long time in advance and also has a long service life. UBA has several projects examining the vulnerability of infrastructure to climate change and is developing approaches to designing climate-resilient infrastructure. The projects are meant to show how today's infrastructures are interlinked and what weak points they have, and what characteristics future infrastructures will have and – in order to be climate resilient and sustainable – should have under the changing conditions. This also involves taking account of social, organisational and institutional consequences associated with the adaptation of existing and alternative infrastructures.

Expertise from the social sciences and humanities will also be incorporated: BMBF's interdisciplinary Social Dimensions of Climate Change and Climate Protection funding initiative contributes towards boosting the level of expertise from these fields in climate research. In a cross-sectoral perspective, UBA is conducting two projects to investigate

how people's ideas of a climate-resilient society could contribute to refining the German Strategy for Adaptation to Climate Change, and what pathways towards that climate-resilient society might look like. Another UBA project has evaluated the options for action open to spatial planners and sectoral planners to adapt settlement patterns and infrastructure to climate change in a way that is accessible for practitioners. Two other UBA projects also focus on supporting practitioners: a project on good practice in climate change adaptation in Germany compiles knowledge on adaptation for stakeholders at regional and local authority level and identifies examples of good practice with the aim of supporting adaptation in business and individual behaviour. A project to empower local authorities focuses on which factors and conditions have a decisive influence on adaptation capacity in local authorities in Germany. Against this backdrop, the project develops proposals and support services for systematically building capacity for adaptation to climate change at the local level. Communication is becoming increasingly important, particularly in applied adaptation research. For that reason, one UBA project is looking at communication on extreme events, with the aim of providing appropriate information for each target group to strengthen people's ability to take their own precautionary measures.

Another topic covered is the national impacts of climate change. In this connection UBA is conducting projects on foreign trade and migration, for example.

The adaptation process in Germany has been and still is shaped by a series of participatory procedures in the course of implementing the German Strategy for Adaptation to Climate Change and the Adaptation Action Plan. Other UBA projects evaluate previous cooperation and participatory procedures in Germany, and test innovative participation formats. Their purpose is to help improve and consolidate climate change adaptation activities that have already been launched at federal, Land and local authority level.

Agriculture

As well as breeding efficient crop varieties that are adapted to changing climatic conditions, in other words resistant to or tolerant of abiotic and biotic stress, the Julius Kühn Institute (JKI) also develops crop cultivation strategies to reduce climate-related risks and devises concepts and strategies to protect crops by adopting appropriate methods in good time in order to counter changes or shifts in the pathogen and pest spectrum caused by climate change. Robust plant growth models for various relevant crop species are produced on the basis of JKI's own long-term field trials, supplemented by field trial data from institutions run by the Länder at multiple locations over many years (including trials of cultivars specific to individual Länder). The models enable JKI to analyse climate-induced changes over time and to develop crop husbandry climate change adaptation strategies that make agronomic, economic and environmental sense.

Forests and forestry

The Forest Climate Fund, jointly managed by BMEL and BMUB, supports several research and development projects concerned with the adaptation of forests to climate change and the sustainable management of forests.

The Thünen Institute is working on the scientific basis for site-appropriate forest conversion and conducts economic assessments as a decision-making aid for carrying out adaptation measures. The introduction and spread of new pests is counteracted by precautionary action taken in good time thanks to the development and establishment of monitoring systems. One particular focus is the conservation of forest genetic resources which plays a crucial role in strengthening forests' capacity to adapt.

8.2.5.8 Carbon capture and storage

In the power station sector and in energy-intensive industries with high process-related CO₂ emissions, carbon capture and storage (CCS) can be regarded as an option for achieving the target of reducing CO₂ emissions by 80–95 %.

Research on geological CO₂ storage was funded from 2005 onwards under the special Geotechnologies programme (2000–2014), which was part of the Research for Sustainable Development framework programme (FONA).

BMBF had a two-pronged funding strategy, covering two types of research: one which sought to answer basic questions about geological CO₂ storage irrespective of any particular location, and the other which explored and operated specific test storage facilities.

Within the research dealing with basic issues, BMBF supported 32 projects with funding of over EUR 30 million. BMBF's involvement in research at specific locations (Altmark natural gas field, Saxony-Anhalt, and the research storage facility at Ketzin, Brandenburg) comprised funding of about EUR 28 million. Funding for research projects on geological CO₂ storage largely ceased upon conclusion of the special Geotechnologies programme at the end of 2014. BMBF funding on this topic stopped completely at the end of 2016.

The Federal Ministry of Economic Affairs and Energy (BMWi) funds applications-oriented research and pilot projects on carbon capture within its energy research funding programme.

8.2.6 International cooperation

The German government has made a firm commitment to assuming global responsibility, which it sees as crucial to implementing the principle of sustainable development (see also Chapter 6).

8.2.6.1 Research for sustainable development of cities of tomorrow

The World Bank estimates that cities account for 80 % of the imminent growth in developing countries and emerging economies. Businesses and urban populations benefit from this growth, but it also poses new challenges: cities are responsible for providing technical infrastructure (such as housing, transport, energy and water) and social infrastructure (such as health systems, schools and jobs) and for maintaining, replacing and financing it.

The funding programme on Research for Sustainable Megacities of Tomorrow focused on energy- and climate-efficient structures in urban growth centres. It demonstrated that economic growth and climate change mitigation are not mutually exclusive. Emerging economies and developing countries gradually became involved in international efforts to mitigate climate change. Nine bilateral transdisciplinary teams of researchers worked on mitigation and adaptation strategies and ways of implementing them for Lima (Peru), Casablanca (Morocco), Addis Ababa (Ethiopia), Gauteng (South Africa), Tehran/Karaj/Hashtgerd (Iran), Hyderabad (India), Ho Chi Minh City (Viet Nam) and Urumqi and Hefei (China). The areas covered were water management, transport/mobility, energy supply/energy management, construction/housing/urban planning, waste management, urban agriculture, and resource conservation. The products of the research include planning instruments, guidelines and appropriate technologies.

Building on this research on future megacities, BMBF will now fund research and development projects on the subject of sustainable development of urban regions. The aim

of this funding measure is to devise and test locally appropriate strategies for sustainable development in urban regions that both improve environmental factors and increase the resilience of cities, and to add extra impetus to the long-term implementation of the strategies.

8.2.6.2 Regional research and service centres for climate change and adaptive land management in Africa

Working with partners from ten countries in West Africa and five countries in Southern Africa, BMBF is setting up two regional competence centres for climate change and sustainable land management in Southern and West Africa (Regional Science Service Centres – RSSCs). The two initiatives, SASSCAL (Southern African Science Service Centre for Climate Change and Adaptive Land Management) and WASCAL (West African Science Service Centre on Climate Change and Adapted Land Use), are designed to assist these regions, which are severely affected by climate change, in establishing scientific structures.

The aim of this activity is to provide targeted support to emerging economies and developing countries in Southern and West Africa in building their own expertise and capacity in applications-oriented research and development on adaptation to climate change and in developing and implementing adapted land management systems (such as systems for managing water availability, land use and ecosystem services). The two centres, SASSCAL and WASCAL, are currently going through a consolidation phase; as they continue their development, responsibility for them will pass to the African partners so that they become independent in the long term.

The centres have placed their focus on applied research, and at the same time have assumed an advisory role in their region for public and private decision-makers. One of their most important tasks will also be to train young scientists from African countries.

Other research partnerships for the assessment of complex Earth system processes in the Southern Africa region are being created as part of BMBF's SPACES research programme. SPACES contributes to the formulation of science-based recommendations to policy-makers for Earth system management and is intended to help ensure the sustainable use and preservation of various ecosystem services in the region. The programme is implemented within the land-ocean system of Southern Africa, taking account of its variability in space and time.

8.2.6.3 Funding programme on International Partnerships for Sustainable Technologies and Services for Climate Protection and the Environment (CLIENT)

Since 2010 the Federal Ministry of Education and Research (BMBF) has funded a programme entitled CLIENT (International Partnerships for Sustainable Technologies and Services for Climate Protection and the Environment). In the period from 2010 to 2017 it has implemented 31 bilateral research and development projects (total funding approximately EUR 60 million) with selected emerging economies and developing countries in the fields of sustainable use of resources, water management, land management and climate change mitigation.

Following on from this, the notice of call for proposals for CLIENT II – International Partnerships for Sustainable Innovations was published in December 2015. Alongside its thematic and regional focus, under CLIENT II the projects will be even more closely geared to demand in the partner country so as to increase the chances of implementation and open up market opportunities for German businesses. The purpose of the projects envisaged in

this programme is to add effective impetus to reducing environmental pollution in the partner countries, utilising natural resources intelligently and sparingly, supplying reliable, clean and affordable energy to all segments of the population and making a contribution to mitigating global climate change and adapting to climate change and natural risks. The issues to be examined are expected to be sufficiently important that potential solutions will generate considerable leverage locally and have an impact on comparable circumstances in other regions.

As well as research and development projects, CLIENT II will also fund definition projects, serving as preparatory measures to pave the way for other projects. Regional project offices in the field will have the task of networking research projects with each other and with stakeholders in the partner country. The first collaborative research projects under CLIENT II were due to be launched from July 2017 onwards. A total of around EUR 100 million will be provided as funding for the measure up to 2023.

8.2.6.4 Integrating research activities into international programmes

BMBF promotes the integration of German global change research into international programmes and enables the scientists involved to participate in them at the national level and be involved in organising international cooperation.

The German IPCC coordination office, which was set up by BMBF and BMUB, works to feed the results of German climate research into the IPCC process and the Fifth Assessment Report. The work carried out by Professor Hans-Otto Pörtner, Co-Chair of IPCC Working Group II, is backed up by funding for a Technical Support Unit based at the Alfred Wegener Institute for Polar and Marine Research.

BMBF and BMUB also set up the German IPBES coordination office, which backs the integration of technical expertise into the work processes of the World Biodiversity Council IPBES (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) and supports essential political advisory and decision-making processes at national level.

BMBF provides EUR 500,000 per annum to develop the United Nations University Institute for Environment and Human Security (UNU-EHS), which was founded in Bonn in 2003. UNU-EHS is one of more than ten research and training centres of the United Nations University located around the world.

8.2.6.5 Joint Programming Initiative Connecting Climate Knowledge for Europe (JPI Climate)

JPI Climate pursues the objective of concerted planning of research funding in key areas of European development (“major challenges”). The intention is that the impact of national and EU R&D funding should be intensified by joint planning, implementation and evaluation of national research programmes. To this end, JPI Climate creates a coordinated pan-European platform where strategies, instruments, resources and stakeholders at national and European level are directed towards common goals. JPI Climate’s core aim is to generate climate knowledge that has a practical effect and supports implementation of the Paris Agreement and the SDGs. The main areas of emphasis are on climate system research, development of a European research area for climate services, cross-sectoral climate impact research and the mobilisation of social sciences, economics and the humanities for climate research. The Joint Programming Initiative is a collaborative platform involving 16 EU Member States. The JPI Climate Secretariat is situated in Brussels.

8.2.6.6 FACCE

The Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI) is an association of currently 22 countries that have set themselves the goal of establishing a network within the European research area and jointly contributing to solving important social challenges in the context of climate change, globalisation, the growing scarcity of resources and demographic change.

It pursues this goal with a strongly transdisciplinary research approach, encompassing economic and social aspects in addition to scientific ones.

The alignment of national programmes and input from multiple actors and interest groups have an important role to play in this.

The integrated FACCE-JPI strategic research agenda defines five core research themes:

1. Sustainable food security in an age of climate change
2. Environmentally sustainable growth and intensification of agricultural systems in light of the current and future climate and the availability of resources
3. Assessing and reducing trade-offs between production, biodiversity and ecosystem services
4. Adaptation to climate change throughout the whole food chain
5. Greenhouse gas mitigation

To date, ten joint research activities have been launched, with funding amounting to about EUR 104 million.

BMEL and BMBF are jointly represented within FACCE-JPI, and together with other member states they run the decentralised secretariat, which Germany (BMEL) has chaired since January 2017.

8.2.6.7 Joint Programming Initiative Healthy and Productive Seas and Oceans (JPI Oceans)

JPI Oceans is an alliance of 22 member states that has adopted a strategic research agenda with ten priorities, two of which are relevant to the climate: climate change impact on physical and biological ocean processes, and effects of ocean acidification and warming on marine ecosystems. The intention is that both of these strategic priorities should be addressed in close collaboration with JPI Climate, and relevant working groups have already been set up.

8.3 Systematic observation and data management

There is still a strong need for observations of the state and development of each individual component in the climate system and for information on systems and structures – both natural and those used by people – which are affected in general terms by climatic or global changes. Germany is therefore continuing to increase its support for the Global Climate Observing System (GCOS).

Earth observation systems are used to acquire this kind of information using in-situ and remote sensing observation techniques. Remote-sensing methods include ground-, air-, water- and space-based systems. A full picture can be achieved only when insights from all the observation systems are integrated. To describe the state of the climate system and

how it is developing, it is particularly crucial to measure internationally defined ECVs (essential climate variables) as completely as possible and with reliability over long periods of time. A more detailed description of Germany's contributions to the Global Climate Observing System can be found in a separate report in English.²⁰⁰ The internationally defined ECVs serve as a guide when determining the climate variables that are important for Germany.

The national GCOS coordinator – an office which has been set up at Deutscher Wetterdienst (DWD), Germany's national meteorological service – acts as an interface between national institutions and organisations and the GCOS programme, and arranges annual GCOS meetings to improve cooperation among the partners. Since October 2015, national implementation of the German contributions to GCOS have been supported by the Interministerial Working Group on Adaptation to Climate Change (IMAA), which also steers national implementation of the Global Framework for Climate Services (GFCS).

The national GCOS coordinators from Germany, Austria and Switzerland are in regular contact. They held a joint GCOS meeting for the first time in 2012, since when they have attended each other's national GCOS meetings.

Many of the observation systems mentioned below can be classed in terms of content or organisation both as research systems and as routine operational observation systems, which makes it difficult to make a clear distinction between them and makes overlaps in content unavoidable.

Many German institutions such as DWD, the Federal Maritime and Hydrographic Agency (BSH), university institutes and Helmholtz Centres continue to participate to a great extent in international monitoring networks observing the atmosphere (WWW, World Weather Watch Programme, and GAW, Global Atmosphere Watch – both WMO programmes), the oceans (GOOS, Global Ocean Observing System) run by IOC (Intergovernmental Oceanographic Commission of UNESCO) and land surfaces (GTOS, Global Terrestrial Observing System) run by FAO (Food and Agriculture Organization). All the climate observation components of these systems together make up GCOS. WMO, IOC, the International Council for Science (ICSU) and the United Nations Environment Programme (UNEP) support the GCOS programme with a joint secretariat at WMO in Geneva. Germany also regularly makes additional voluntary contributions to fund the implementation of activities and running of the GCOS secretariat.

8.3.1 Atmosphere

DWD's statutory duties include monitoring the atmosphere. The Alfred Wegener Institute for Polar and Marine Research (AWI) also carries out activities in this field, as do the Länder in the specific field of chemical ECVs. In addition to traditional in-situ measuring methods, remote-sensing techniques such as ground-based radar are used for monitoring precipitation, and satellite-aided systems are used for identifying different ECVs. DWD operates extensive observation networks, which include conventional meteorological and climatological observation stations as well as a network of weather radars. In addition to the continuous operation of these observation networks, it also carries out extensive quality assurance and archiving activities.

Since German reunification in 1990, a uniform standard has been used for collecting and archiving the data. The increased use of automatic stations means that data is now

²⁰⁰ Deutscher Wetterdienst (to be published soon).

available in a time resolution of one to ten minutes. The number of stations operated by DWD depends on the particular ECV. It currently has 1,910 observation stations for precipitation (as at 1 April 2017).

To extend the time frame for usable climate data, since 2005 DWD has been making constant efforts to digitise historic data that is currently available only on paper or other non-electronic media. It also participates in the international exchange of meteorological and climatological data. With its two meteorological observatories, DWD is also involved in scientific studies of atmospheric processes to enhance the understanding of the climate system.

DWD runs national reference stations where traditional and automated measuring systems are operated in parallel in order to identify systematic differences between the two. The stations were chosen for location (North Sea, North German Plain, uplands, highlands) and for the quality and length of the observation series already available.

DWD and AWI participate in the GCOS Surface Network (GSN) with four stations and one station respectively. In conjunction with the Japan Meteorological Agency, DWD operates a centre for monitoring the availability and quality of the data provided by the GSN stations.²⁰¹ On behalf of the WMO (World Meteorological Organization) Commission for Basic Systems (CBS), DWD also runs one of nine CBS Lead Centres for GCOS in the world.

DWD and AWI also participate in the GCOS Upper Air Network (GUAN) with one station each. On behalf of WMO, DWD runs the Lead Centre for the GCOS Reference Upper Air Network (GRUAN), which involves coordinating quality assurance of the radiosonde measurements in GRUAN worldwide. As a rule, GRUAN stations are a subset of the GUAN stations, carrying out observations to a particularly high standard of quality. Germany contributes to GRUAN with one DWD station and one AWI station. DWD also makes other contributions to GCOS and to WMO's World Climate Research Programme (WCRP).

DWD's two meteorological observatories play a particularly important role, carrying out extensive long-term monitoring of physical and chemical processes in the atmosphere. All data is subject to strict quality control. Germany (AWI) has also been responsible for operating the World Radiation Monitoring Center (WRMC) since the beginning of 2008.

Satellites have become an indispensable source of the information needed to identify and evaluate changes in the climate system. They provide continuous data quickly and with blanket coverage, particularly for regions where coverage by other measuring systems is poor. Germany is the major partner in all the European satellite programmes connected with climate monitoring that are run by ESA, the EU and EUMETSAT. Germany also uses the satellites that are part of its national space programme to contribute to the climate observation system and operates the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT), for example, at DLR. Planning and operation of meteorological satellites in Europe is carried out by the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) in Darmstadt. Germany, represented by DWD, is the largest partner in EUMETSAT and is closely involved in decisions on ongoing and proposed fleets of satellites. One of the focuses of EUMETSAT's programme is climate monitoring. It has two long-term satellite systems, MSG (Meteosat Second Generation), which is geostationary, and MetOp (Meteorological Operational satellite), which is in polar orbit. They make an important contribution to establishing long-term atmospheric

²⁰¹ <http://www.gsnmc.dwd.de>

observation for climate monitoring, using instruments that previously could be made available only for short periods of time on research satellites.

To provide satellite products for different groups of applications, EUMETSAT has built up a network of thematic application facilities known as Satellite Application Facilities (SAFs). Their purpose is to develop and archive application-based satellite products and deliver them on an ongoing basis.

The development and generation of specialist products for observing the climate system is carried out jointly by EUMETSAT and the partners in the European Consortium CM SAF (Satellite Application Service for Climate Monitoring), which is operated by seven national meteorological services in Europe, with DWD as lead agency. CM SAF has broadened the focus of its activities in recent years and now also delivers high-calibre, regional and global long-term climatologies of satellite-derived parameters (such as on solar and thermal radiation, population, humidity distribution and precipitation). Operational data from CM SAF thus supports the tasks of the WMO Regional Climate Centre (RCC) network in monitoring the climate in Europe.²⁰² CM SAF, working on behalf of EUMETSAT and headed by DWD, occupies a leading position in Europe.

Various facilities have been set up in Germany as part of the European ICOS (Integrated Carbon Observation System) research infrastructure: Central Analytical Laboratories, an atmospheric measurement network (currently five out of nine stations, the remainder in 2017/18), and ocean and ecosystem locations for measuring long-lived climate gases CO₂, CH₄ and N₂O and the ECV precursor CO. The national measurement networks and central facilities deliver high-quality data, standardised across Europe, which is used by scientists in model validation (for example the Copernicus Atmosphere Monitoring Service, CAMS) and inverse modelling, and which also contributes to services such as WMO's Integrated Global Greenhouse Gas Information System (IG3IS). ICOS is an important element in the system of verifying emission reductions in Europe.

A European research infrastructure similar to ICOS, ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure), is currently being created for aerosol parameters and aerosol and ozone precursors, i.e. short-lived climate forcers (SLCFs), in which Germany is aiming to play an important role with observational networks (DWD, UBA, other research establishments) and central facilities connected with calibration laboratories. ACTRIS will also play an important part in monitoring emission reductions and improving the understanding of processes.

Various institutions in Germany also participate in the Satellite Application Facility on Atmospheric Composition Monitoring (SAF for Atmospheric Composition Monitoring, AC SAF).

HALO (High Altitude and Long Range Research Aircraft) has taken aircraft-based atmospheric research to a new level. The aircraft was built by Gulfstream for DLR, and following extensive testing is available for use in Germany's research programmes. DLR in Oberpfaffenhofen has lead responsibility for operating HALO. HALO is able to reach altitudes as high as the lower stratosphere, enabling the German and international scientific community to carry out studies of unprecedented quality. HALO's main research priorities include areas that are of key importance for the climate and the occurrence of extreme weather events, such as studies on precipitation formation and transport of humidity and cloud water, atmospheric self-cleaning processes and chemical and dynamic processes in

²⁰² <http://www.rccra6.org/rcccm>

the transition zone between the troposphere and stratosphere. German environmental and climate researchers have already carried out numerous missions.

8.3.2 Oceans

Germany's contributions to the observation of oceanographic ECVs are shared by numerous institutions that support the Global Ocean Observing System (GOOS). They include the Federal Maritime and Hydrographic Agency (BSH), the Alfred Wegener Institute for Polar and Marine Research (AWI), ZMAW (Center for Marine and Atmospheric Sciences at Hamburg University), DWD, GEOMAR Helmholtz Centre for Ocean Research, IUP Bremen and others. Research vessels (such as the RV Sonne and RV Polarstern) and merchant ships, as well as drifting and anchored buoys and remote-controlled vessels, are used as measuring platforms. Some of the activities are supported by research funds and some are part of commercial activities. For example, Germany provides about 30 to 40 ARGO drifters a year, and within WMO's VOS (Voluntary Observing Ship) programme equips a fleet of about 457 merchant ships with meteorological instruments (as at 1 April 2017). The Federal Maritime and Hydrographic Agency is lead agency in coordinating oceanographic observations and for GOOS.

8.3.3 Land surfaces

Numerous national institutions are also involved in observing terrestrial ECVs. Germany contributes to the Global Terrestrial Observing System (GTOS), the climate components of which are part of GCOS. For example, the global data and product centres for runoff (Global Runoff Data Centre, GRDC, hosted by the German Federal Institute of Hydrology – BfG) and precipitation (Global Precipitation Climatology Centre, GPCC, based at DWD) make valuable contributions to the Global Terrestrial Network for Hydrology (GTN-H) and the Global Terrestrial Network for River Discharge (GTN-R). DWD also carries out observations of plant phenology. It has not yet been possible to establish a central coordination point for GTOS in Germany, and the international GTOS Secretariat, which is financed by FAO, has not been staffed for a number of years.

The observation of forests is also worthy of mention. These methods and data will remain important in the context of the Paris Agreement, global forest monitoring and REDD+. European Union and German initiatives such as Sentinel and TerraSAR-X collect vital data in this field.

8.3.4 Cryospheric climate observations

Cryospheric climate observations relate to the few glaciers and occurrences of permafrost in Germany and observation stations operated by Germany in other countries.

The Department for Geodesy and Glaciology at the Bavarian Academy of Sciences and Humanities has conducted glacier observations for many decades. As well as monitoring the five glaciers in Germany (Northern and Southern Schneeferner, Höllentalferner, Watzmann Glacier and Blaueis), it has kept the Vernagtferner in the Ötztal Alps under close observation since 1974. Investigations are also carried out in other glacier regions, such as Iceland, Norway, the Pamir Mountains and the Karakoram. Modern satellite techniques are used in addition to the traditional field measurements used in geodesy and glaciology. The data obtained in this way forms the basis for modelling the interactions between glaciers and their environment as a function of climatic changes. The observation data is regularly

made available to international data centres such as the World Glacier Monitoring Service (WGMS²⁰³) and the National Snow and Ice Data Center (NSIDC²⁰⁴).

Permafrost is found at only a few locations in Germany. Only the permafrost at the summit of the Zugspitze is constantly monitored; the data is sent to the EU's PermaNET project.²⁰⁵ In addition, permafrost working groups from the Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) support permafrost observation stations in northern Siberia, Spitzbergen, Alaska and Northwest Canada.

Through its national and international observation activities, Germany also contributes to the Global Terrestrial Network for Glaciers (GTN-G) and Permafrost (GTN-P). Furthermore, the GTN-P Secretariat is located at AWI in Potsdam.

8.3.5 Multi-source remote sensing observation systems

Satellites offer unique advantages in identifying and assessing changes in the climate system. They provide continuous data quickly and with blanket coverage. Some parameters can only be determined using satellites. Germany is the major partner in all the European satellite programmes connected with climate monitoring that are run by ESA, the EU and EUMETSAT.

Experimental (Earth Explorer) satellites, such as SMOS and CryoSat-2, which were part of the ESA Earth observation programme, have been of key importance in studying processes within the climate system. ESA has also successfully established the Climate Change Initiative programme (www.esa-cci.org), which was launched in 2010. The Initiative generates ECVs from satellite data and in particular ensures that the ESA archives of satellite data are processed and used scientifically. Germany has made a disproportionately large financial contribution to this programme and plays a leading role. German institutions such as DWD, DLR, and IUP Bremen have assumed responsibility for deriving atmospheric GCOS variables in this context.

With the Copernicus/GMES (Global Monitoring for Environment and Security) programme, jointly initiated by ESA/EU, Europe is ensuring long-term continuity for many other climate-related observations, especially satellite observations. The first phase of the third part of the ESA programme was adopted at the end of 2012 and will complete the development of the GMES Space Component by about 2020. The EU is responsible for operating the systems and setting up the services. Alongside GALILEO, the Copernicus/GMES system is Europe's most important contribution to the Global Earth Observation System of Systems (GEOSS).

Germany makes further contributions to observing the climate system with input from its national space programme. Data provided by the German radar satellite TerraSAR-X has been used since 2007 to detect ice sheets, for example, as well as many other climate parameters. The TanDEM-X mission is used to generate a global elevation model that is an important basis for many climate-related issues.

Higher carbon dioxide emissions and changes in land use have led to a rapid rise in CO₂ in the atmosphere in recent years (see report by the Global Carbon Project 2016). CO₂ monitoring will also be an important task for Earth observation systems in future (such as the Integrated Carbon Observation System – ICOS²⁰⁶).

²⁰³ <http://wgms.ch/>

²⁰⁴ <http://nsidc.org/index.html>

²⁰⁵ <http://www.permanet-alpinespace.eu>

²⁰⁶ <https://www.icos-ri.eu/>

Under its renewable resources funding programme, BMEL funds development of the Global Risk Assessment Services (GRAS) tool. The aim is that GRAS should be developed into an innovative internet platform that provides information about environmental and social sustainability: GRAS will help agricultural and forestry producers, processors, brand owners, traders, NGOs, scientists and investors to review sustainability risks for individual farms, catchment areas or countries. The tool is also designed to help certification systems, certification bodies and auditors with objective and consistent sustainability analysis and the verification of land use changes.

In the current project, changes in land use are to be documented by evaluating high-resolution remote sensing data and data from the latest generation of satellites. New technologies and methods will be tested experimentally in order to obtain the most accurate information possible in difficult situations (small-scale plots, different regions and crops) and for new applications (forestry). Smallholders will be integrated into the system as part of the landscape approach. Documentation of supply chains should be traceable and transparent, and environmental and social sustainability aspects should be comprehensively recorded and described, and grouped together according to risk factors.

8.3.6 Data and information management

A range of different information systems is available in Germany to assist users in searching for data using data catalogues and meta-databases, in some cases with direct online access. The central access point to the Spatial Data Infrastructure Germany (GDI-DE) is Geoportal Germany (www.geoportal.de). In terms of organisation and implementation, it is already providing a central search facility at national level for researching and using distributed geodata and geo services.

Sharing environmental data in Germany is regulated by the Spatial Data Access Act (Geodatenzugangsgesetz) of 10 February 2009.

Geoportal Germany, which is constantly being expanded, gives access to information systems connected with geoinformation. A selection of these systems is described below.

The Federal Maritime and Hydrographic Agency (BSH) collects oceanographic data acquired by German institutions at the German Oceanographic Data Centre (DOD).

The Marine Data Infrastructure Germany (MDI-DE), operated in the context of cooperation on the design and development of software for environmental information systems (KoopUIS), provides data and information on coastal engineering, the protection of coastal waters, marine environmental protection and marine nature conservation via a joint internet portal and supports data searches and the use of data. MDI-DE helps authorities in the coastal zone to fulfil their reporting obligations under EU framework directives such as MSFD and INSPIRE.

The Marine Environmental Data Base (MUDAB) is a joint project between UBA and the central database in the monitoring programme for the marine environment of the North Sea and Baltic, which is jointly run by the federal and Länder governments. MUDAB is operated by the German Federal Institute of Hydrology in Koblenz.

The Deutscher Wetterdienst (DWD) runs the National Climate Data Centre (NKDZ), which contains the meteorological observations from the various networks of monitoring stations in the Federal Republic of Germany and the statistical parameters derived from them, along with time series dating back to the 18th century. Data on specific physical and chemical issues is collected at the meteorological observatories. International data centres with

global datasets also provide data, which is added to this national data. They include GPCP with global precipitation analyses, CM SAF with climate monitoring products from satellite data and satellite-based climatologies, and the Global Collecting Centre (GCC), which provides global maritime data. The Climate Data Centre (CDC) at DWD has created a central portal providing access to all this data; it is continuously being improved.

In addition to the national climate archive, DWD also collects and archives the international data collected under WMO's World Weather Watch programme and disseminated by the Global Telecommunication System (GTS). In conjunction with the Japan Meteorological Agency (JMA), Deutscher Wetterdienst also runs a centre that monitors the availability and quality of climate data from stations in the GCOS Surface Network (GSN). DWD deals with precipitation data and JMA with temperature. With external support in the field of atmospheric physics, the Federal Environment Agency (UBA) is setting up one of three centres worldwide for data quality assurance and control within Global Atmosphere Watch (GAW).

The German Climate Computing Centre (DKRZ) in Hamburg acts as a supraregional service centre, carrying out climate simulations and operating the technical facilities needed to process, analyse and share relevant data. To improve sharing of climate-related model data, DKRZ is part of a system of national and international databases available to German and other European partners. This means that this climate model data can be accessed by both scientific institutions and major research institutes in Germany.

Paleoclimate databases are run by the Alfred Wegener Institute for Polar and Marine Research (with the PANGAEA information system, which includes the paleoclimate database PKDB at Hohenheim University) and the GFZ German Research Centre for Geosciences.

Other examples of information systems providing data on the state of the environment in Germany are the landscape information systems of the Federal Agency for Nature Conservation (LANIS), relevant information systems at the Federal Office for Agriculture and Food (BLE), the KLIMAPS information system at the Julius Kühn Institute (JKI) and the various information systems of the Länder.

The Soil Information System at the Federal Institute for Geosciences and Natural Resources (BGR) is maintained in close collaboration with the geological offices of the Länder (Staatliche Geologische Dienste, SGD). It contains and shares nationwide data on soil. The data is used in virtually every supraregional and national development and advisory project related to land use and changes in land use. It is updated and quality assured on an ongoing basis and harmonised with other countries in Europe under international agreements.

Germany has the following data and information systems relating to international activities:

DLR's Applied Remote Sensing Cluster stores, manages and analyses satellite remote-sensing data. The DLR institutes that belong to the cluster are involved in numerous national, European and international activities related to sharing satellite-based climate variables. They include data systems as part of relevant soil segments, such as ERS-1/2 and Metop, a World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT), and the development of algorithms for climate variables. Users can obtain DLR's products on the internet at DLR's EOWEB.

The Julius Kühn Institute (JKI) has set up a Research Centre for Agricultural Remote Sensing (FLF). In so doing it is responding to the growing importance and potential of

remote sensing applications for the derivation of satellite-based climate variables in the context of agriculture.

International data centres for data relevant to the global hydrological cycle have been set up in Germany as part of WCRP (both of them key components of GCOS and GEOSS):

- At the Deutscher Wetterdienst (DWD), the Global Precipitation Climatology Centre (GPCC), which provides global precipitation analyses for climate monitoring and climate research
- At the German Federal Institute of Hydrology (BfG), the Global Runoff Data Centre (GRDC)

Central archives of data collected worldwide have been established, including one for marine research at the GEOMAR Helmholtz Centre for Ocean Research as part of IGBP's core project JGOFS, and one for paleontological data at the Alfred Wegener Institute for Polar and Marine Research (AWI). Under the WCRP core project WOCE, data assimilations (dynamic interpolation of data using global models) are performed at a Special Analysis Centre (SAC) at the Max Planck Institute for Meteorology (MPI-Met) and in conjunction with the Federal Maritime and Hydrographic Agency (BSH).

Further information can be found in the 2013 Deutscher Wetterdienst publication entitled "Die deutschen Klimabeobachtungssysteme. Inventarbericht zum Global Climate Observing System (GCOS)" and the more detailed National GCOS Report (in the annex to the National Communication).

8.3.7 Support for emerging economies and developing countries

German contributions to supporting emerging economies and developing countries in establishing and operating observation systems and systems for data management and climate monitoring are described below.

Responsibility for technical development cooperation in Germany lies with the Federal Ministry for Economic Cooperation and Development (BMZ), while for scientific and technological cooperation it lies with the Federal Ministry of Education and Research (BMBF).

The Global Atmosphere Watch (GAW) Training & Education Centre (GAWTEC) has been training scientists for GAW stations since 2001. It is financed by funds from UBA and the Bavarian State Ministry of the Environment and Consumer Protection.

Support for emerging economies and developing countries in establishing and operating observation systems and systems for data management and climate monitoring is usually only a subsidiary part of a project on a different topic. This is why Germany has set up climate databases and data management systems as part of the SASSCAL (Southern African Science Service Centre for Climate Change and Adaptive Land Management) project funded by BMBF, with support from DWD. This project will be completed at the end of 2017.

The Enhancing Climate Services for Infrastructure Investment (IKI-CSI) project, financed by funds from BMUB's International Climate Initiative (IKI), was launched in April 2017, with the aim of improving the use of climate services in certain selected countries.

Agencies such as DWD do not have their own funds that would enable them to provide direct support to partner meteorological services in emerging economies and developing

countries. Germany has provided financial support for the international GCOS Secretariat for a number of years.

Relevant activities relating to support for emerging economies and developing countries in establishing and operating observation systems and systems for data management and climate monitoring often form part of wider-ranging cooperation projects (see sections 6.4 and 6.5).

9 Education, training and public awareness

9.1 Fundamental orientation of educational policy and public awareness work on climate action

The complex environmental, economic and social challenges posed by climate change require action-oriented training and education that can creatively impart the necessary technical, scientific and social problem-solving skills.

Effective action to achieve transformative environmental protection and climate action that will help shape societal changes requires more than knowledge about interconnections and interactions. What we have to do is create a wide variety of opportunities to test and improve this knowledge in actual practice.

The training and education services offered by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) follow the principles of Education for Sustainable Development (ESD) in providing action-oriented, participatory civic education.

Because Education for Sustainable Development involves civic education, it promotes the capacity to engage in dialogue, provides the background knowledge needed to make decisions, and encourages creative and critical thinking. It fosters willingness to assume responsibility for one's own actions, cope with uncertainties and contradictions, solve problems, and participate in shaping a democratic, culturally-diverse society.

The primary concern is to further increase opportunities for children and young people to participate. In keeping with the United Nations 2030 Agenda for Sustainable Development, importance is also accorded to issues related to social justice, cultural diversity, and gender equality.

9.2 Resources for primary, secondary and university education

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety offers a variety of action- and participation-oriented educational resources on climate change and climate action. While they are mainly intended for the primary and secondary levels, they are appropriate for all types of schools. The resources are addressed to teachers at all levels of general and vocational education and training, as well as multipliers outside of schools. The emphasis is on making resources available on the portal at www.umwelt-im-unterricht.de, which offers lesson plans for two-week units covering current environmental issues and events such as UN climate change conferences.

The resources and other offerings are available without registration and are completely free of charge when used for teaching. With just a few exceptions, the content is available under "open" (Creative Commons) licenses that allow users to disseminate and publish materials in amended form.

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety funds education projects under the National Climate Initiative (NKI) to increase awareness about climate action among teachers and students and encourage them to get involved in practical action for the climate. Some representative projects are described below.

As part of the “Soko Klima” project, a briefcase full of methods for getting children and young people involved in formal and informal planning procedures at the municipal level which are relevant to climate issues was developed. The briefcase can be used to motivate children and young people to participate actively in plans affecting their immediate environment.

During the “KlimaKunstSchule” project, artistic means were used to explore the subject of climate change. A total of 50 artists “planted artistic seeds” in 200 German schools to motivate students to express their ideas about climate change in alternative ways, opening up new perspectives.

In the “Klasse Klima” project, students are invited to live a climate-friendly lifestyle both at home and at school. Participation, an orientation to action, and the interests of students determine the point of departure for climate action projects in the participating schools.

In the “KlimaAktionsKinos” project, climate action and sustainable mobility are communicated through physical movement. Young people produce their own films, which are presented as part of a national bicycle cinema tour and at participating youth hostels.

The Educational Service of the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety has published a monthly newsletter since 2008 to provide current information on its activities and on projects, events, and publications in the area of education for sustainable development. Events, competitions, and materials from various areas are presented on the Educational Service’s central website. In this way, the Educational Service contributes to effective network communication.

As part of its climate action campaign, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety funds the “Energiesparmeister” energy conservation contest to increase awareness of energy conservation among schools, students and parents. Prizes for the most innovative, creative and efficient climate action projects in German schools are awarded each year. A jury selects the best school project in each Land and awards the title of “energy conservation champion” to 16 schools. Each champion receives €2,500 and is sponsored by a partner from a company or other organization supporting the contest. The sponsorships are intended to promote sustainability and build bridges between the different parts of civil society.

9.3 Public information campaigns

The German government decided in its Climate Action Plan 2050 to continue to develop a culture of participation in the context of climate action, thereby initiating and strengthening learning and innovation processes. It is guided in particular by the criteria of certain UN Sustainable Development Goals: achieving gender equality (SDG 5), reducing inequality (SDG 10), and effective and inclusive public institutions (governance; SDG 16). In addition to opportunities for participation, the public needs easily accessible ways to participate, for example at the district or neighbourhood level, because this enhances understanding of and commitment to climate action.

It will be important for local authorities, the Länder, businesses, and organisations – in some cases with financial support from the federal government – to provide information, offer training, and strengthen ongoing efforts by giving them appropriate recognition.

The federal government provides constant support for climate action, the energy transition and resource efficiency in the form of public awareness work (including information campaigns).

9.3.1 Information campaign on the Climate Action Programme 2020

The “Zusammen ist es Klimaschutz” campaign was launched in connection with the Climate Action Programme 2020. It increases public awareness about climate issues, offers tips on reducing greenhouse gas emissions in everyday life and provides information on current climate policy trends. The campaign includes brief advertising spots that can be downloaded from its website²⁰⁷ and from YouTube. The wide range of items available on the Internet and on social media is rounded off with a poster campaign and appearances at various events.

9.3.2 Campaigns on the energy transition

The wordmark “Die Energiewende: Ein gutes Stück Arbeit” and accompanying logo have been used since mid-2014 in communications about current priorities and other messages to the general public, companies, local authorities and multipliers.

The focus in summer 2014 was initially on reform of the Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG). The reorientation of the EEG to increase predictability and make increased use of renewables more affordable was publicised and explained by comprehensive editorial content on bmwi.de and erneuerbare-energien.de and in online banners, ad placements and advertorials in energy trade publications, daily newspapers and general-interest magazines. Flyers, brochures, workshops and published reports increased transparency in the eyes of multipliers and the public.

From mid-2015 to spring 2016, the public was informed about (funding) measures under the National Action Plan on Energy Efficiency (NAPE) and made aware of the need to increase energy efficiency. The emphasis was on energy-efficient building refurbishment and heating with renewables (market incentive programme). In addition to flyers, fact sheets and web content, over four million copies of a special publication in magazine format by the Federal Ministry of Economic Affairs and Energy (“Zukunft leben”) containing numerous examples of best practices and listing specific funding opportunities was distributed as an insert in media of interest to appropriate target groups.

Other communicative content on the energy transition included the positive results of implementation (October-December 2015), particularly progress in increasing the use of renewable energy and the economic stimulus associated with the energy transition. This was also the subject of the special publication entitled “Die Energiewende: unsere Erfolgsgeschichte,” which used concrete facts, figures, interconnections, and trends to highlight the success of the energy transition and was distributed throughout Germany in leading national media in early 2017.

The German government launched the “Deutschland macht’s effizient” campaign in May 2016 to emphasise the many advantages of energy efficiency for companies, private consumers, and municipal and social infrastructure. The aim is to provide comprehensive information to increase the awareness of the public, companies and local authorities in a way that will motivate them to use electricity and heat wisely and invest in measures to improve energy efficiency in the home, workplace and local authority buildings. It offers complete, easy-to-use information on the advisory services and funding programmes related to energy efficiency measures offered by the German government. The centrepiece of the campaign is the website www.machts-effizient.de. It is supplemented by

²⁰⁷ <http://www.bmub.bund.de/ziele/>

publications, advertisements, signs, an advertising spot shown in cinemas, and hands-on activities (dance cube and selfie box). Associations, companies, the Länder and local authorities can support the campaign by using the available logos, distributing information material or linking to the website. The aim of the campaign is to make broad swaths of the target groups more aware that energy efficiency is an integral part of the energy transition, inform them about options for action and the available potential and reach all target groups that share responsibility for achieving climate action targets.

The purpose of the Energy of the Future monitoring process is to be able to review and, if necessary, make adjustments to the implementation of measures and targets that are part of the energy transition and the energy concept, including the goal of achieving a reliable, affordable and environmentally sound energy supply. The government publishes the results annually in a monitoring report. In addition to the regular monitoring, every three years a progress report provides a more comprehensive view of the energy transition, enables analyses to be conducted in greater depth over a longer period and also looks to the future. The reports are submitted to the Bundestag (lower house of parliament) and Bundesrat (upper house).

A commission of independent energy experts supports the monitoring process. The expert commission gives a scientific opinion of the government's monitoring and progress reports. The monitoring process helps to increase the transparency of the energy transition and thus raise the level of acceptance.

9.4 Education and training programmes

9.4.1 Vocational Training for Sustainable Development funding programme

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety has placed all of its offerings in this area under the Vocational Training for Sustainable Development – Key Green Skills to Facilitate Climate-Friendly and Resource-Efficient Working Practices funding programme as part of the current 2014-2020 funding period of the European Social Fund (ESF).

This is the first federal programme in the more than 50-year history of the ESF with an explicit focus on the environment and climate action. Four of the 14 projects funded during the first round of funding that began in 2015 relate to specific climate action measures. Trainees and the participating educational actors learn during hands-on courses how the interfaces between the building trades can be improved. If a house is understood to be a system and the trades cooperate effectively, the result will be high-quality energy-efficient refurbishment of existing buildings and construction of new builds.

The following four projects focus on climate action measures:

- HAKS – Training the Trades for Climate Action, <http://haks-projekt.de/>
- Nabus – Sustainable Building and Refurbishment, <https://weiterbildung.nznb.de/>
- KoopBau – Cooperative Action – Building Sustainably Across the trades, <http://www.koopbau.info/>
- Moebus – Modules for Energy-Efficient Building and Refurbishment, <http://www.moebus.hbz.de/>

9.4.2 Training Initiative for Building Efficiency I – Build Up Skills

The BUILD UP Skills – QUALITRAIN project uses funds from the European Union to support training and continuing professional development for people working in the construction industry and the establishment of a national training platform.

9.4.3 Training Initiative for Building Efficiency II - ESF programme contribution

The Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) is also creating a funding programme under the European Social Fund (ESF) to offer training in energy-efficient building refurbishment for different building trades. The focus is on informal practical training outside of the traditional classroom for apprentices and trainers.

9.5 Information and advisory services

9.5.1 Energy Export Initiative

The German government's Energy Export Initiative offers support to German providers of climate-friendly energy solutions so they can successfully position themselves in international markets. It actively contributes to global climate action by promoting the use of climate-friendly energy technologies all over the world. The Export Initiative's website at www.german-energy-solutions.de is flanked by brochures, a newsletter, and events.

9.5.2 SME Initiative for Energy Reforms and Climate Change Mitigation

The initiative was jointly established by the German government, the Association of German Chambers of Commerce and Industry (DIHK) and the German Confederation of Skilled Crafts (ZDH). It supports small and medium-sized enterprises in implementing the energy transition. The aim is to leverage additional potential for energy conservation in companies and to improve their energy efficiency. The initiative has offered practical assistance and arranged for local contacts since 2012, providing an opportunity for dialogue along with information and training. It has been so successful that it is being continued from 2016 to 2018 and expanded to include additional companies, associations, and energy advisors. Specifically, the German government will step up the dialogue between policy-makers and SMEs, optimise information and advisory services, and promote exchanges of experience in the long term.

9.5.3 Renewables

In addition to the website www.erneuerbare-energien.de, which offers up-to-date information, the German government's measures related to renewables are made accessible to the general public in a variety of publications. They include publications related to renewable energy and comprehensive technical information on the development of renewables in Germany, published annually in German as "Erneuerbare Energien in Zahlen" and in English as "Renewable Energies – the Figures." Abundant information about reductions in greenhouse gas emissions resulting from the use of renewables is also provided. The satellite website www.erneuerbare-energien.de also contains links to PowerPoint presentations that contain graphics and tables.

9.5.4 Information from the German Energy Agency (dena)

The German Energy Agency (dena) has been informing private households and companies about measures and the background of efficient, rational use of energy and electricity and the possibilities for using renewable energies in buildings, electric mobility, and efficient energy systems since 2002. Its website keeps people informed with numerous studies, brochures and information, and it holds events and carries out projects on the aforementioned subjects. Since the agency was founded, it has offered stakeholders all over Germany a centralised, constantly growing source of information on the possibilities for efficient use of energy and renewable energy sources.

10 Literature

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11 List of German legislation cited

Primary legislation (federal)

Act on Levying Mileage-Based Charges for the Use of Federal Motorways and Highways	Gesetz über die Erhebung von streckenbezogenen Gebühren für die Benutzung von Bundesautobahnen und Bundesstraßen
Allocation Regulation	Zuteilungsverordnung
Autobahn Toll Act for Heavy Goods Vehicles	Autobahnmautgesetz für schwere Nutzfahrzeuge
Circular Economy Act	Kreislaufwirtschaftsgesetz
Combined Heat and Power Act, CHP Act	Gesetz zur Förderung der Kraft-Wärme-Kopplung
Electricity Market Act	Strommarktgesetz
Electricity Tax Act	Stromsteuergesetz
Energy Conservation Act	Energieeinsparungsgesetz
Energy Consumption Labelling Act	Energieverbrauchskennzeichnungsgesetz
Energy Industry Act	Energiewirtschaftsgesetz
Energy-Related Products Act	Energieverbrauchsrelevante-Produkte-Gesetz
Greenhouse Gas Emissions Trading Act	Treibhausgas-Emissionshandelsgesetz
Packaging Act	Verpackungsgesetz
Project Mechanisms Act	Projektmechanismengesetz
Renewable Energy Sources Act	Erneuerbare-Energien-Gesetz, EEG
Spatial Data Access Act	Geodatenzugangsgesetz
Water Management Act	Wasserhaushaltsgesetz

Secondary legislation (federal)

Landfill Regulation	Deponieverordnung
Incineration and Coincineration of Waste Regulation	Verordnung über die Verbrennung und Mitverbrennung von Abfällen
Biological Waste Treatment Plants Regulation	Verordnung über Anlagen zur biologischen Behandlung von Abfällen
Wastewater Regulation	Abwasserverordnung

Fertiliser Application Regulation	Düngeverordnung
Allocation Regulation	Zuteilungsverordnung
Chemicals and Climate Protection Regulation	Chemikalien-Klimaschutzverordnung
Tax Capping Efficiency System Regulation	Spitzenausgleich-Effizienzsystemverordnung
Energy Conservation Regulation	Energieeinsparverordnung
Charging Point Regulation	Ladesäulenverordnung
Commercial Waste Regulation	Gewerbeabfallverordnung

Länder legislation

Bavarian Compensation Regulation	Bayerische Kompensationsverordnung
Bavarian Forest Act	Bayerisches Waldgesetz
Bavarian Nature Conservation Act	Naturschutzgesetz
Bavarian Soil Protection Act	Bayerisches Bodenschutzgesetz
Bavarian Spatial Planning Act	Bayerisches Landesplanungsgesetz
Bavarian Water Act	Bayerisches Wassergesetz
Climate and Energy Act (Bremen)	Klimaschutz- und Energiegesetz
Climate Change Act (Baden-Württemberg)	Klimaschutzgesetz
Climate Change Act (North Rhine-Westphalia)	Klimaschutzgesetz
Climate Change Act (Schleswig-Holstein)	Klimaschutzgesetz
Energy Transition Act (Berlin)	Energiewendegesetz
Energy Transition and Climate Change Act (Schleswig-Holstein)	Energiewende- und Klimaschutzgesetz
State Climate Change Act (Rhineland-Palatinate)	Landesgesetz zur Förderung des Klimaschutzes
State Climate Change Act (Rhineland-Palatinate)	Landesklimaschutzgesetz
State Development Act (Saxony-Anhalt)	Landesentwicklungsgesetz
State Development Plan (Saxony)	Landesentwicklungsplan
State Development Plan (Thuringia)	Landesentwicklungsplan

State Forest Act (North Rhine-Westphalia)	Landesforstgesetz
State Nature Conservation Act (Hesse)	Landesnaturschutzgesetz
State Spatial Planning Act (Hesse)	Landesplanungsgesetz
State Spatial Planning Act (North Rhine-Westphalia)	Landesplanungsgesetz
State Water Act (North Rhine-Westphalia)	Landeswassergesetz

Translators' note: The English translations of German legislation cited should be seen as descriptive, rather than official. In particular, there may be discrepancies from previous texts published by German government agencies in which *Verordnung* has been translated as Ordinance. We believe that *Verordnung* corresponds more closely to secondary legislation commonly known in the English-speaking world as a Regulation or Regulations.