Federal Ministry
for Economic Affairs
and Climate Action

Eighth National Communication and fifth Biennial Report of the Federal Republic of Germany under the United Nations Framework Convention on Climate Change

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1 Summary

Background

The present report on climate protection in Germany is the eighth National Communication and the fifth Biennial Report of the Federal Republic of Germany to the Conference of the Parties pursuant to Article 12 of the UN Framework Convention on Climate Change, Article 7 of the Kyoto Protocol and Decision 2/CP 17.

The National Communication presents Germany's climate-protection policies in light of the relevant legislative, political and socio-economic framework, discusses the impacts of climate changes and describes the policies and measures that have been initiated in the interest of reducing greenhouse-gas emissions and adapting to climate changes. In addition, it describes the impacts of such measures, including the impacts to date and those projected. Finally, it reports on the topics of financial support; technology transfer; training and education; and provision of information to the public.

The data on which the report is based refer, depending on availability, to the years 1990–2020, and are supplemented with information that takes account of current developments. The eighth National Communication on Climate Protection in Germany has been prepared on the basis of the existing UNFCCC Guidelines on reporting National Communications[1], taking account of the report of the technical review of the 7th National Communication.

Along with this National Communication, Germany is submitting its fifth Biennial Report, as an annex to the National Communication. The format for the Biennial Report was decided at the 17th Conference of the Parties (CoP), held in Durban in 2011[2]. For the group of Annex I countries, which includes Germany, reporting obligations for the National Communication and the Biennial Report coincide every four years, and this has occurred in the present case. The basis for the Biennial Report consists of table formats decided at the 18th Conference of the Parties, held in Doha.

Current status of German climate policy

Since the appearance of Germany's last National Communication, in December 2017, Germany's climate-protection policy has continued to develop in a dynamic way:

- In 2019, Germany adopted a Climate Change Act (Klimaschutzgesetz). In 2021, an amendment to the Act was adopted that set forth more-ambitious goals. In its Climate Change Act, Germany has now committed itself to achieving greenhouse-gas neutrality by 2045 and to achieving a negative emissions balance from 2050 onward. The Act also calls for emissions reductions of at least 65 % by 2030, and of at least 88 % by 2040, with respect to 1990 levels.
- On 9 October 2019, the German Federal Government adopted the Climate Action Programme 2030, a comprehensive range of measures of which most have already been implemented. Currently, an immediate climate action programme is being prepared, with a view to ensuring compliance with the ambitious reduction pathways set forth in the amended Climate Change Act.
- In summer 2022, the German Federal Government adopted an emergency package of energy-focussed measures ("Energiesofortmaßnahmenpaket") that will accelerate the expansion of renewable energies even further. This legislation provides for

[1] Decision 6/CP 25
[2] Decision 2/CP 17

ensuring that at least 80 % of Germany's gross electricity consumption is met by renewable energies by the year 2030.

- As of the year 2020, Germany's total GHG emissions had decreased by about 41 % with respect to 1990 levels.
- Pursuant to the estimates in the 2021 Projections Report, the measures adopted through August 2020 will reduce emissions by about 49 % by 2030, with respect to 1990 levels (and by -36 % with respect to 2005 levels), and by about 67 % by 2040, with respect to 1990 levels (-59 % with respect to 2005 levels). The planned immediate climate action programme in particular is expected to close the gap remaining to what is needed to achieve the climate goals for 2030.
- Also, the German Federal Government has further intensified its activities in the area of climate finance: In 2019, Germany already fulfilled an intent that had been announced in May 2015, at the Petersberg Climate Dialogue, by then German Chancellor Angela Merkel, calling for Germany to double its climate-finance commitment, from two billion euro annually (in 2014) to four billion euro annually (in 2020). At the 2022 Petersberg Climate Dialogue, German Chancellor Olaf Scholz then again confirmed the commitment that former Chancellor Merkel had made at the 2021 G7 Summit in Carbis Bay, calling for increasing Germany's budget-funded contribution to international climate finance to at least 6 billion euro per year by no later than 2025.

In its climate-protection policy, Germany continues to emphasize a mix of measures and instruments. Via laws and ordinances, it creates regulatory frameworks. In the process, it also establishes financial incentives that can influence the behaviour of the relevant stakeholders. At the same time, other economic instruments, such as European emissions trading, play an active role by providing price signals that affect the actions of stakeholders. In addition, funding programmes play a supporting role, by promoting efforts such as technology research; use of renewable energies; measures to eliminate obstacles and to foster acceptance for climate action and to improve energy efficiency, via advising and information provision; and measures to support networking and public participation. Adaptation measures also play an important role. Finally, Germany is also fulfilling its international responsibility, by providing suitable financial support and facilitating technology transfer.

1.1 National circumstances

The report describes the following national circumstances that are of relevance with regard to climate action: legislation; population growth; economic development; geography; climate and climate changes; energy; transport; industry; commerce, trade and services; waste/wastewater; buildings; agriculture and forestry.

Environmental protection in Germany's Basic Law (constitution)

Since 1994, protection of vital natural resources has been enshrined as a national goal in the Basic Law (Grundgesetz) of the Federal Republic of Germany. The Federal Republic of Germany is a federal state in which a Basic Law governs the assignment of competencies to the federal government and the Länder (the individual states of the nation). The various areas of environmental law are assigned to the area of "concurrent legislation." This means that the German Länder (individual states) have legislative power as long as the federal government does not make use of its own legislative capacity. At the same time, the federal

government remains able to shape environmental legislation and to transpose EU Directives in the environmental sector.

Population and area

As of the reporting date 31 Dec. 2020, Germany's Federal Statistical Office reports a population of 83.155 million for Germany. Also according to the Federal Statistical Office, Germany's total area in 2020 was 357,587 km².[3]

Climate profile

Overall, Germany's climate is a warm-temperate rainy climate typical for middle latitudes. The average annual temperature for the period 1961 – 1990, for the area between the isle of Sylt and the Zugspitze (Germany's highest peak), was 8.2 °C. In the period 1991 – 2020, it increased to 9.3°C. An average of 1544 hours of sunshine was recorded in the period 1961 – 1990, and an average of 1665 hours was recorded in the period 1991 – 2020. Throughout the entire year, predominantly westerly winds bring damp air masses from the Atlantic, and provide precipitation of 789 (791) l/m^2 per year. The oceanic influence on Germany's climate ensures that the country's winters are mild and its summers are not overly hot.[4] From 1881 to 2021, the areal mean of Germany's air temperature increased by about 1.6 °C. And this temperature trend has accelerated in recent decades. With a mean temperature of 9.8°C, the decade 2011-2020 was 2°C warmer than the first 30 years of the 1881–1910 observation period, while in the previous decade (2001–2010) this positive anomaly had amounted to only 1.4 °C. With regard to precipitation, the following changes occurred: With respect to the end of the 19th century (1881), the areal mean of the annual rainfall in Germany increased by about 8 %. That said, the rainfall trends exhibit spatial and seasonal differences within Germany. For example, winter rainfall has increased, and summer rainfall has decreased (but not by enough to offset the winter increases). As to wind speeds, no significant trends have yet emerged.

Economic development

Germany's gross domestic product in 2020 was 3,405 billion euro. As a result of the coronavirus pandemic, it was about 2 % lower than it was in the previous year, however. The per-capita gross domestic product in 2020 was 40,950,- €.[5]

Energy sector

As of 2021, primary energy consumption in Germany had decreased by 16.7 % with respect to its level in 1990. And in 2020, energy consumption reached the lowest-ever level seen in the time series since 1990. In fairness, it must be noted that this was due to special effects related to the global coronavirus pandemic. In 2021, energy consumption increased again markedly (by 4.4 %), although consumption in 2021 was still at the second-lowest level seen throughout the time series.

On the one hand, the long-term decreasing trend results in that primary energy consumption is determined via the physical energy content method. On the other, it also is due to real efficiency increases. That said, the especially low primary energy consumption seen in the years since 2020 is due primarily to the impacts – including follow-on impacts – of the coronavirus pandemic.

[3] Cf. the website of the German Federal Statistical Office (Statistisches Bundesamt)– Area and population. As checked on 25 Nov. 2022, URL: https://www.statistikportal.de/de/bevoelkerung/flaeche-und-bevoelkerung
[4] German Meteorological Service (Deutscher Wetterdienst 2022)
[5] German Federal Statistical Office (Statistisches Bundesamt 2021)

Final energy consumption has decreased only slightly since the 1990s. The highest final energy consumption seen in this period occurred in 1996. Since then, through 2021, final energy consumption decreased by 10.5 %. While efficiency increases were achieved in many areas, they were largely offset by economic growth and increased consumption.

The sectoral structure of final energy consumption has changed: The industry sector's share of total final energy consumption decreased from 31.4 % in 1990 to 29.0 % in 2021. A similar development occurred in the sector commerce, trade and services; its share of total final energy consumption decreased slightly, from 18.6 % to 16.0 %. Private households' share increased from 24.9 % to 27.8 %. The transport sector's share increased from 25.1 % to 27.1 %. On the other hand, the transport sector's energy consumption was especially low in 2021, due to the impacts of the coronavirus pandemic. In 2019, the year prior to the pandemic, its share was 30.3 %.

For the most part, the roles of the various fuels and energy sources involved have shifted considerably, in terms of their relative importance. In 1990, lignite and hard coal met 36.9 % of primary energy consumption. By 2021, their share of that consumption had decreased to less than half of their share in 1990 (18.0 %). Petroleum's large share of primary energy consumption has remained unchanged. In 2021, it was somewhat lower (32.5 %) than it had been in 1990 (35.1 %). It must be noted that petroleum consumption in 2021 decreased primarily as a result of the coronavirus pandemic's impacts on the transport sector. In 2019, the year prior to the pandemic, petroleum's share of total energy consumption was about as large as it had been in 1990 (35.2 %). At the same time, renewable energy sources have become considerably more significant; their share increased from 1.3 % in 1990 to 15.7 % in 2021. Natural gas has also grown in significance, with its share increasing from 15.4 % to 26.6 %. Since the country's decision to phase out nuclear power, nuclear energy has no longer played a significant role. in 2021, it accounted for only 6.1 % of primary energy consumption.[6]

Renewable energies' share of gross electricity generation continued to grow in 2021, and it reached 40.1 %, which is just as large as the shares for lignite, hard coal and nuclear energy combined. At the beginning of the 1990s, those energy sources still accounted for a share of over 80 %. Natural gas's share has grown from 6.5 to 15.6 % since 1990. In 2021, the largest contribution to gross electricity generation from renewable energies, 38.6 %, came from onshore wind energy. Offshore wind energy accounted for a contribution of 10.4 %. Other important renewable energy sources included photovoltaic systems, accounting for a contribution of 21.1 %, and biomass, with a contribution of 18.9 %.

Since the mid-2000s, Germany's electricity exports have grown considerably. In 2017, they reached their maximum level – about 52.5 TWh, or 8.1 % of gross electricity generation. In subsequent years, electricity exports decreased again, considerably. In 2021, they amounted to 18.6 TWh, or 3.2 % of electricity generation.[7]

Transport sector

The development of transports between 1991 and 2019 was shaped by a medium-level increase in passenger transports (measured in billions of passenger-km, Table 1) and by strong growth in goods transports (measured in tonne-km, Table 2). In 2020, passenger

[6] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022) Auswertungstabellen zur Energiebilanz 1990 bis 2021 (26 September 2022) URL: https://ag-energiebilanzen.de/daten-und-fakten/auswertungstabellen/

[7] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022) Bruttostromerzeugung in Deutschland nach Energieträgern. URL: https://ag-energiebilanzen.de/wp-content/uploads/2022/04/STRERZ21_Abgabe-09-2022A11.pdf

transports decreased considerably, as a result of the Covid-19 pandemic and the contact and travel restrictions it entailed. Goods transports were also affected – although less strongly – as a result of supply-chain disruptions.

Industry sector

In Germany, industry – to a far greater extent than in comparable countries – is a key basis for growth, prosperity and jobs. In 2021, it accounted for about 755 billion euro of gross value added and some 10 million employees.[8]

Industry is the central basis of Germany's export strength. Germany is a global leader in many industrial sectors, such as the automotive industry, machinery and plant engineering and the chemical and pharmaceutical industries. The structure of Germany's industry sector is shaped especially by manufacturing of machinery and vehicles, which accounts for 42 % of gross value added.

Waste / wastewater

A total of 51.0 million t (tonnes) of municipal waste were produced in Germany in 2020[9]. The recycling/recovery rate for all municipal waste amounted to 98 % in 2020, or an increase of 27 percentage points over the corresponding figure in 2006. The recycling rate in 2020 was 67 %.

Along with municipal waste, the following quantities of other waste types were produced in 2020: 28.6 million t of waste from extraction and processing of mineral resources, 229.3 million t of construction and demolition waste, 47.3 million t of other waste (in particular, waste from production and industry), and 57.7 million t of waste from wastewater treatment plants (see 2.9.6).

Overall, some 10 billion m^3 of wastewater are treated in public and industrial wastewater treatment plants (*Federal Statistical Office, 2021*). Of the approximately 1.7 million t of sewage sludge produced in public-sector wastewater treatment plants, about 0.3 million t are used as fertiliser in agriculture (*Federal Statistical Office, 2020*) (see 2.9.6).

Building sector

The energy-related application areas tied directly to use of buildings include space heating, production of hot water, cooling (air conditioning) and space illumination, in the consumption sectors industry, and commerce, trade and services (GHD). The building-related final energy consumption in these areas in 2020 amounted to 835 TWh. This quantity of final energy consumption in the building sector was 125 TWh, or 13 %, lower than the corresponding figure for 2008.

Agriculture

In 2020, some 262,800 farms in Germany managed about 16.6 million ha of agricultural land. In comparison to the corresponding figure for 2016, the number of farms was reduced by about 4.6 %. Between 2010 and 2020, the decrease in the number of farms was even higher, amounting to 12.1 %. The average farm size in 2020 was about 63 ha.[10] The

[8] German Federal Statistical Office: gross value added, adjusted for price (Statistisches Bundesamt 2022, Bruttowertschöpfung preisbereinigt).
[9] German Federal Statistical Office (Statistisches Bundesamt 2022) Abfallwirtschaft Kurzübersicht Abfallbilanz – Zeitreihe. URL: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Abfallwirtschaft/Tabellen/liste-abfallbilanz-kurzuebersicht.html#613014
[10] German Federal Statistical Office (Statistisches Bundesamt - GENESIS-Online, 2022) https://www-genesis.destatis.de/genesis/online

agricultural sector's contribution to Germany's GHG emissions (not including LULUCF emissions) was about 8°% in 2020.[11]

Forestry sector

Pursuant to the first comprehensive survey of forestry-sector structures, Germany had about 10.2 million ha of forest land in 2022[12]. 4.4 million ha, or 43 % of the total forested area, are privately owned. The total number of private forest owners is about 760,000. About 3.3 million ha of state forest (32 %) are managed by the competent forest administrations of the German states (Länder). A total of 2.2 million ha (22 %) of the forested area is allocated to local authorities (bodies governed by public law, such as special-purpose associations, and municipalities). Federally owned forest land, totalling only 310,000 hectares (3 %) of the total forested area, accounts for far and away the smallest share of Germany's total forested area.

1.2 Information about the GHG inventory

As a party to the UN Framework Convention on Climate Change, Germany has been required since 1994 to prepare inventories of its national GHG emissions. On 14 April 2022, Germany published its 1990-2020 GHG inventories and its latest National Inventory Report (2022 NIR). From 10 through 15 October 2022, the national GHG inventories submitted by the parties to the Framework Convention were reviewed by an international team of experts. The NIR 2022 describes, in detail, the methods and data sources on which the calculations of German GHG emissions are based. The descriptions provided in the present report are based on the 2022 NIR. The NIR presents tables of data on the direct GHG gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (laughing gas; N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

Reduction obligations

In February 2005, the Kyoto Protocol entered into force. As a result, the international community of nations is required to implement binding action objectives and instruments for global climate protection. In the first commitment period, which lasted from 2008 through 2012, the European Community (at the time, with 15 Member States) committed itself to reducing its greenhouse-gas emissions by 8 % with respect to the base year (1990 and 1995[13]). This commitment has been divided and fulfilled within the EU in the framework of a burden-sharing agreement between the participating Member States[14]. In that agreement, Germany agreed to reduce its emissions by 21 % in comparison to the base year and thus agreed to make a substantial contribution to fulfilment of the EU's commitment. With a reduction of over 26 % by 2012, Germany exceeded that goal.

In the framework of the second commitment period of the Kyoto Protocol, the European countries (now, the European Union) have committed themselves to reducing their GHG emissions by 20 % by 2020. At the same time, they have announced that, under certain

[11] German Environment Agency (Umweltbundesamt 2022): https://www.umweltbundesamt.de/presse/pressemitteilungen/treibhausgasemissionen-stiegen-2021-um-45-prozent

[12] Press rease oft he German Federal Statistical Office (Statistisches Bundesamt 2022) https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/09/PD22_415_41161.html

[13] For HFC, PFC and SF_6

[14] Burden-sharing agreement, adopted with Council Decision 2002/358/EC of 25 April 2002 concerning the approval, on behalf of the European Community, of the Kyoto Protocol to the United Nations Framework Convention on Climate Change and the joint fulfilment of commitments thereunder [OJ L 130 of 15 May 2002]

conditions, this European contribution could be increased to a 30 %[15] reduction with respect to 1990.

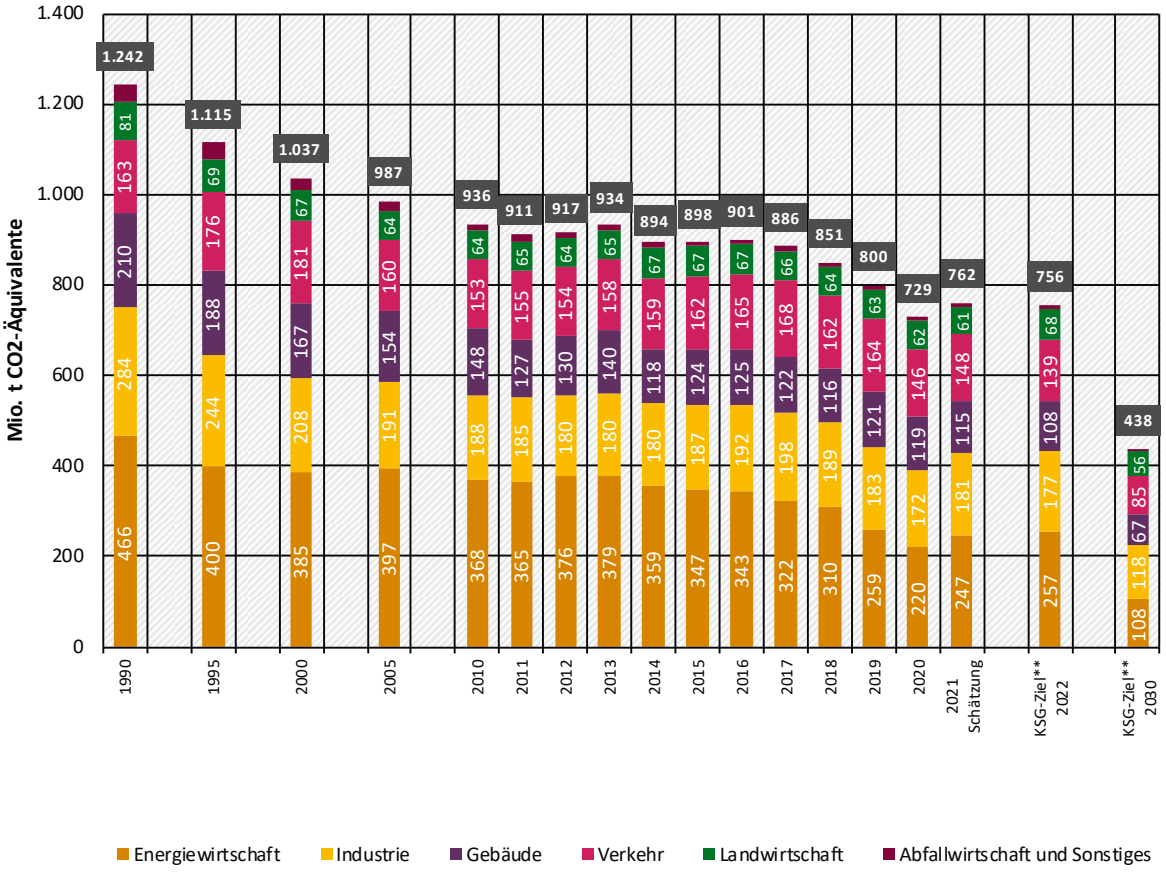
Breakdown of GHG

In 2020, with an 87.7 % share, carbon dioxide emissions again accounted for the largest share of greenhouse-gas emissions. Most of the carbon dioxide is released via stationary and mobile combustion of fossil fuels. As a result of a disproportionately large reduction of other greenhouse-gas emissions, CO_2 emissions' share of total emissions has increased by about 3 percentage points since 1990. Methane (CH_4) emissions, caused predominantly by animal husbandry, fuel distribution and landfills, accounted for a 6.7 % share. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and burning of fossil fuels, contributed 3.9 % of greenhouse-gas releases in 2020. Fluorocarbons (so-called "F gases") accounted for about 1.7 % of total emissions.

This breakdown of greenhouse-gas emissions in Germany is typical for a highly developed and industrialised country.

Emissions trend

[15] Information on the quantified emission limitation or reduction objectives (QELROs) for the second commitment period under the Kyoto Protocol; SUBMISSION BY DENMARK AND THE EUROPEAN COMMISSION ON BEHALF OF THE EUROPEAN UNION AND ITS MEMBER STATES, Copenhagen, 19 April 2012



* The emissions breakdown diverges from relevant figures provided in the context of UN reporting. The total emissions are identical, however.

** In keeping with the amendment of the Federal Climate Change Act (KSG) of 12 May 2021; the years 2022-2030 have been adjusted to take account of overruns and & underruns

Figure 1: Development of GHG emissions in Germany, by categories; Source: German Environment Agency (2022)[16]

On the whole, greenhouse-gas emissions decreased by 41.3 % in 2020, with respect to 1990 levels[17]. Considerations of the various components involved confirm this trend, to varying degrees. The relevant emissions changes for the most important greenhouse gases in terms of quantity were as follows: - 39.2 % for carbon dioxide (CO_2), - 58.7 % for methane (CH_4) and - 51.4 % for nitrous oxide (N_2O). The corresponding trends for the called "F" gases, which contribute about 1.7 % of greenhouse-gas emissions overall, have not been as consistent, however. In keeping with the introduction of new technologies, and with use of these substances as substitutes, since base year 1995 SF_6 and PFC emissions have decreased, while HFC emissions increased. In total, emissions of F gases have decreased by 28.9 % since 1995, however.

With respect to the previous year (2019), total emissions decreased by 8.9 %. That reduction was the largest seen since 1990, the year of German reunification. For the most part, the reduction seen is due to structural changes in the energy industry, as well as to pricing

[16] Translation: emissions in Mio. t CO_2-equivalent; Energiewirtschaft = Energy Industries; Industrie = Industry, Gebäude = Buildings, Verkehr = Transport, Landwirtschaft = Agriculture, Abfallwirtschaft und Sonstiges = Waste and other; 2021 Schätzung = estimate for 2021; KSG-Ziel = target as given in the Federal Climate Change Act (KSG)
[17] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

factors such as low gas prices, and high prices for CO_2 certificates within European emissions trading.

In addition, CO_2 emissions from electricity generation decreased again in 2020. Use of hard coal and lignite also decreased again. In recent years, use of natural gas has increasingly been supplanting coal in electricity generation, and its specific CO_2 emissions are lower than those of coal. Also, renewable energies' share of electricity generation has increased markedly.

1.3 Policies and measures

In its Climate Change Act, Germany has obligated itself to achieve net greenhouse-gas neutrality by the year 2045[18]. In addition, the Act calls for emissions to decrease by at least 65 percent by 2030, and by at least 88 percent by 2040 (both with respect to 1990 levels). The Federal Climate Change Act defines a range of maximum permissible annual emissions quantities for various different sectors (energy, transport, buildings, etc.), for the period through 2030.[19]

Compliance with these annual emissions quantities, in the various sectors involved, is reviewed on an annual basis. To this end, on 15 March of each year, and making use of the National GHG Inventory, the German Environment Agency publishes the emissions data for the previous year. If it is determined that a given sector has exceeded its maximum permissible annual emission quantities, the federal ministry responsible for the relevant sector is required to propose measures to ensure that the sector will comply with its sector-specific allotments in subsequent years.

In its *Climate Action Programme*, the German Federal Government sets forth the measures that it plans to implement in order to enable Germany to achieve its national climate-protection goals in the various individual sectors involved. On 9 October 2019, the German Federal Government adopted the comprehensive Climate Action Programme 2030. Currently, the Federal Government is working, in the context of an immediate climate action programme, to adopt additional reduction measures, with a view to closing the gap remaining to what is needed in order for Germany to achieve its climate goals through 2030. Via climate-protection reports, the German Federal Government reports annually on the status of implementation of the country's climate action programmes and on the reduction effects the programmes achieve.

In keeping with the widely differing sector-specific challenges involved, the Federal Government is relying on a broad range of instruments, including regulatory law, CO_2 pricing, funding programmes, fiscal incentives, advising and various support services aimed at participating stakeholders. The following section presents a few selected pertinent measures that have already entered into force and that are contributing to Germany's compliance with its climate goals:

Since 2005, European emissions trading has been the central, cross-cutting measure for GHG-emissions reduction in Germany. Emissions trading obligates operators of energy generation installations, and of installations in energy-intensive industries, to submit certificates for their GHG emissions of the relevant previous year.

[18] Pursuant to Sec. 2 (9) of the amended Federal Climate Change Act, defined as: "the balance between the anthropogenic GHG emissions from sources and the removal of such gases via sinks."
[19] For the energy industry sector, the Federal Climate Change Act (Klimaschutzgesetz, KSG) establishes maximum permissible annual emissions quantities for the years 2020, 2022 and 2030.

On 1 January 2021, a national emissions trading system for the heat and transport sectors was adopted. It takes account of CO_2 emissions from combustion of fossil fuels (especially heating oil, LP gas, natural gas, coal, gasoline, diesel fuel and waste fuels). Unlike the EU Emissions Trading Scheme, the national emissions trading scheme is designed to focus not on direct emitters, as the causers of emissions, but on the upstream trading level, i.e.: on the companies that place fuels on the market.

On 24 June and on 7 July 2022, the German Bundestag (lower house of parliament) adopted what amounts to the most significant set of energy-policy amendments to appear in decades. The measures included amendments of the Renewable Energy Sources Act (EEG), of the Offshore Wind Energy Act (Windenergie-auf-See-Gesetz) and of the Energy Industry Act (Energiewirtschaftsgesetz – EnWG) and other energy-industry laws, and they included the introduction of an Act on space requirements for wind energy (Windenergie-bedarfsflächengesetz). These measures will accelerate expansion of renewable energies in a comprehensive way – offshore, onshore and on rooftops. In sum, they are expected to ensure that at least 80 % of Germany's gross electricity consumption are being met by renewable energies by 2030.

With still another group of measures, the German Federal Government is moving forward with the transition to electromobility: For example, through the year 2025, newly registered electric cars will be exempted from vehicle taxation through the end of 2030. Furthermore, in taxation of private use of company cars, battery-electric vehicles and plug-in hybrids will be subject to reduced rates through 2030. At the same time, expansion of the charging infrastructure is being moved forward systematically.

The funding guideline "Decarbonisation in industry" supports projects in energy-intensive industries aimed at achieving the largest-possible, long-term reductions of process-related GHG emissions that, according to the current state of the art, are either unavoidable or extremely difficult to prevent.

Via the investment programme "Energy efficiency and process heat from renewable energies in industry" ("Energieeffizienz und Prozesswärme aus erneuerbaren Energien in der Wirtschaft"), the German Federal Government is consolidating and refining a number of existing funding programmes (highly efficient cross-cutting technologies, climate-friendly production processes, avoidance and use of waste heat, energy management systems and renewable process heat).

A Federal Funding for Efficient Buildings (BEG) programme is now providing the first-ever unified funding structure covering both residential buildings and non-residential buildings: the BEG programme, which consists of several sub-programmes, has supplanted the many different funding programmes in the building sector that have developed over time – including the well-known CO_2 Building Rehabilitation Programme (KfW programmes for energy-efficiency construction and modernisation ("Energieeffizient Bauen und Sanieren")). With this programme, funding of energy efficiency and renewable energies in the building sector is now being consolidated, for the first time, under one umbrella.

Funding for new buildings will be restructured in 2023. A new programme, entitled "Climate-friendly new buildings" ("Klimafreundlicher Neubau"), is refining the quality seal for sustainable construction. In the process, it is placing greater emphasis on consideration of GHG emissions throughout buildings' entire life cycles.

Also, numerous other measures, including both European and nationwide German measures, are addressing the climate-relevant sectors of energy; buildings; transport;

industry; trade, commerce and services; agriculture and forestry; waste management; and water-resources management.

In addition, the German Länder (states) and the country's municipalities are implementing relevant measures of their own. All 16 of the German Länder now have their own climate-action concepts, programmes, plans or laws in place. And many municipalities have defined pertinent goals and are preparing their own climate action concepts and measures.

1.4 Projections, and effects of measures

For the German 2021 Projections Report, a research consortium, working on behalf of the German Environment Agency, prepared a scenario for the development of GHG emissions in Germany in the period 2021–2040. The "with-measures scenario" (WMS) part of the projection takes account of all climate and energy policies and measures that, as of 31 August 2020, had been introduced or significantly modified in the various sectors involved. The projections for the agriculture and LULUCF sectors were calculated by the Thünen Institute.

With regard to *total GHG emissions* (not including emissions from land use, land-use changes and forestry, or from international air and sea transports), an emissions reduction of about 49 %, with respect to 1990 levels, results by the year 2030 (-36 % with respect to 2005 levels), and a reduction of about 67 %, with respect to 1990 levels (-59 % with respect to 2005 levels), results by the year 2040. In light of the sensitivities considered in the report, an emissions-reduction corridor emerges for 2020 that, with regard to the relevant 1990 levels, lies between 33.7 % (stronger economic growth) and 37.5 % (lower electricity-export balance).

1.5 Vulnerability, climate impacts and adaptation measures

In 2020, the German Federal Government published the Second Progress Report on the German Strategy for Adaptation to Climate Change (DAS) and adopted the third Adaptation Action Plan (APA III), comprising some 180 measures.

Also, a network of 28 higher federal authorities and institutions, working on behalf of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, prepared a Germany-wide, cross-cutting climate-impacts and risk analysis for the period through 2100 (KWRA 2021[20]). The results of the KWRA 2021 confirm that all of Germany will be affected by climate change. The expected impacts of climate change include a further increase of the average temperature, more-frequent and more-intense regional drought and heat, and more-frequent and more-intense heavy rainfall events. Such impacts will differ from region to region. Some impacts, for example, such as rising sea levels and greater river flooding, will occur only in certain regions. The disastrous floods of 2021, caused by unusually heavy rainfall, made this fact clear.

Climate change poses a threat to both a) natural systems and resources, and b) future generations. Protection of natural systems and resources plays a vital role in prevention of domino effects. Many climate risks can be reduced via adaptation measures.

The current Federal Government's coalition agreement makes important new climate-adaptation instruments available to the Federal Ministry for the Environment, Nature

[20] https://www.umweltbundesamt.de/publikationen/KWRA-Zusammenfassung

Conservation, Nuclear Safety and Consumer Protection (BMUV). They include the Federal Government's German Strategy for Adaptation to Climate Change (DAS)[21]) of 2008. Plans call for that strategy to be developed, within the framework of the available budget resources, into a precautionary climate-adaptation strategy, including the following triad of measures:

- A legal framework, in the form of a climate-adaptation act;
- The development of concrete, measurable climate-adaptation goals;
- The coalition agreement calls for provision of joint Federal/Länder financing, at adequate financial levels, for climate-protection and climate-adaptation measures. Also, it calls for providing greater latitude for innovation, digitalisation and private private-sector initiatives in the areas of climate adaptation. The BMUV is currently reviewing the options for implementation of such efforts.

Measures in this framework will require long-term, careful preparation. For this reason, and in a first step, the BMUV has launched an immediate climate action programme (Sofortprogramm Klimaanpassung)[22].

1.6 Financial support and technology cooperation

The German Federal Government is one of the largest donors worldwide in the area of international climate finance. The government had aimed to double its contribution in this area by 2020, via a jump from 2 billion euro in 2014 to 4 billion euro (including budgetary resources and grant equivalents from development loans). That goal was already exceeded in 2019. From 2005 through 2020, the federal government increased its climate financing from public budgetary resources to 5.05 billion EUR / 5.77 billion USD.[23][24] Since 2013, in addition to reporting on its climate financing from public-sector budgetary resources, Germany has also reported on climate-relevant loan financing provided by KfW Development Bank and DEG (Deutsche Investitions- und Entwicklungsgesellschaft mbH), with the help of market resources. Since 2015, such reporting has extended to individual projects. In 2020 – and in addition to the budgetary resources used in this area – KfW and DEG made 2.55 billion EUR / 2.91 billion USD in loan commitments from capital-market funds. The federal government aims to achieve a suitable balance between its climate financing for emissions-reduction projects and its financing for adaptation to climate change. In 2020, of the Federal budgetary resources allocated in this area, 60% were used for reduction measures and 40% were allocated to adaptation measures. In its international cooperation in the area of climate and development, the German Federal Government makes use of a broad spectrum of instruments and channels.

[21] https://www.bmuv.de/themen/klimaschutz-anpassung/klimaanpassung/die-deutsche-anpassungsstrategie
[22] https://www.bundesregierung.de/breg-de/themen/klimaschutz/sofortprogramm-klimaanpassung-2019928
[23] Conversion via the OECD reference exchange rates for 2017 and 2018; https://data.oecd.org/conversion/exchange-rates.htm
[24] In addition, in 2017 funding of 23 million EUR / 26 million USD was provided for the Annex I countries Ukraine, Turkey and Belarus. In 2018, funding in the amount of 66 million EUR / 78 million USD was provided for the Annex I countries Ukraine, Turkey, Russia and Belarus.

1.7 Research and systematic observation

Many government ministries in Germany, along with their subordinate or associated institutions, play an active role in funding research on the topics of renewable energies, energy efficiency, sustainable mobility, sustainability, climate change and adaptation to climate change. Issues related to climate change, for example, are being studied in the framework of the strategy “Research for Sustainability” (FONA) of the Federal Ministry of Education and Research (BMBF), of the Federal Government’s 7th Energy Research Programme and of the departmental research programmes of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry of Food and Agriculture (BMEL).

The many different research activities underway cover the following areas:

- The climate system; variability and interactions in the earth system
- Observation and data management
- Climate impacts research
- Energy and mitigation research, including technology research
- Adaptation to climate change, and assessment of climate impacts
- Socio-economic research into the causes and consequences of climate change

Also, Germany continues to expand its support for the Global Climate Observation System (GCOS). The efforts being made in this context include the support being provided by Germany's National Meteorological Service (DWD), along with various German research institutions, for the GCOS Surface Network, the GCOS Upper Air Network for atmospheric observation, the Global Ocean Observing System and the Global Terrestrial Observing System (GTOS). Since October 2015, national implementation of Germany’s GCOS participation is being politically supported by the Interministerial Working Group on Adaptation to Climate Change, in keeping with Art. 6 of the UN Framework Convention on Climate Change. Germany supports the establishment and operation of observation systems, of data-management systems and of systems for climate monitoring in developing countries.

1.8 Education, training and measures to raise public awareness

The German federal government supports sustainable development via targeted training and education, especially in connection with the process for establishment of education for sustainable development in the German education system. Via suitable concepts and projects, the government supports environmental education in schools and in vocational training. In addition, it supports numerous education projects in Germany in the framework of the National Climate Protection Initiative (NKI).

The federal government also addresses the issues of climate action and the country’s energy system transformation via publicity campaigns, and it provides resources for informing the public and raising public awareness. Via communication and dialogue, the government is working to make the country’s citizens aware of the need for active climate policy.

Active public relations also regularly play a basic role in funding programmes and projects relative to climate action. Nearly all projects focussed on national and international climate

action, on the country's energy system transformation and on mobility issues are supported by communication measures.

2 National circumstances

2.1 Key data

2.1.1 How Germany is structured

The Federal Republic of Germany is a federation of 16 states ("Länder"). The Basic Law governs the division of responsibilities between the federation and the Länder. The administrations of the Länder are generally organised in three levels: 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 Working Group on Climate and Sustainability (BLAG KliNa). Federal-Länder summits to implement the Energiewende, Germany's transition to a new energy era, have been held twice a year since 2012 at the invitation of the Chancellor.

2.1.2 Environmental protection as a national goal

Since 1994, protection of vital natural resources has been enshrined as a national goal in Art. 20a the constitution (the "Basic Law," or Grundgesetz) of the Federal Republic of Germany. In addition, a Climate Change Act was adopted in 2019, aimed at enabling Germany to achieve greenhouse-gas neutrality.

2.1.3 Legislation and enforcement

Legislative authority is shared between the federation and the Länder. The federation has exclusive powers of legislation in certain areas allocated to it under the Basic Law.

The various areas of environmental law are assigned to the area of "concurrent legislation." This means that the federation can both shape environmental legislation and transpose EU Directives in the environmental sector. The federation has the power of concurrent legislation when uniform regulation is necessary.

All federal laws are submitted to the Bundestag and the Bundesrat, with some laws requiring "acts of consent" and some requiring "acts of objection", depending on their content.

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

As a member of the European Union, the Federal Republic of Germany transposes relevant agreements made by that union. Like the German Basic Law, the Treaty on European Union and the Treaty on the Functioning of the European Union[25] frame sustainable development and improvement of the environment as overarching goals. In the areas environment,

[25] Treaty on the Functioning of the European Union of 26 Oct. 2012, at http://eur-lex.europa.eu/legal-content/DE/TXT/PDF/?uri=CELEX:12012E/TXT&from=DE (German version, last checked on 29 May 2017)

energy, transport and agriculture, which are areas of key significance for climate action, the EU and its Member States share competencies. In these areas, the Member States have regulatory competence in cases in which the EU fails to exercise its competence.

A great many of the environmental laws in Germany are based on EU decisions, issued either as directives, which the Member States are required to transpose into their own national legislation, or as regulations, which have direct legal effect in the Member States.

2.2 Population[26]

According to the latest population census, about 83.2 million people lived in Germany at the end of 2020. Of that number, 49.3% were male, and 50.7 % were female. As a result, Germany's population size remained virtually unchanged with respect to 2019. Some 67.0 million persons (81%) lived in the former territory of the Federal Republic (former West Germany), while 12.5 million (15 %) lived in the new German Länder and 3.7 million (4.4%) lived in Berlin.

From the end of 1990, the year of German reunification, through the end of 2002, Germany's population increased from 79.8 million to 82.5 million (+2.8 million). Then, the population declined until the year 2010. In 2011, the population began increasing again. Pronounced population growth occurred in the years 2014 through 2016, as a result of high levels of immigration. During this period, the largest number of immigrants (+978,000 persons) was registered in 2015. Population growth remained robust in the years 2017 and 2018 (2017: +271,000; 2018: + 227,000 persons). It was somewhat lower in 2019 (+147,500). From 2019 to 2020, Germany's population remained nearly unchanged (-12,000). Overall, Germany's population grew by 2.4 million persons (+3.0%) in the years 2014 through 2020. In 2020, the population density for Germany as a whole was 232.5 inhabitants per km².

According to the main variants of the 14th coordinated population projection, which was carried out in 2019, Germany's population will continue to grow until at least 2024, and it will begin to decrease by no later than 2040.

Germany's demographic trends differ sharply by region. For one thing, population growth between 2014 and 2019 was concentrated in cities: In 2014, a total of 55.8 million people lived in communities with fewer than 100,000 inhabitants. By the end of 2019, the total population of such communities had grown by 1.8 %, or by 1.0 million people. During the same period, the total population of cities with 100,000 or more inhabitants grew by 3.7 %, to 26.3 million (+ 1.0 million). In addition, the differing trends seen in the eastern and western parts of Germany continued after German reunification. For example, the population in the territory of former West Germany grew continuously (except in the years 2006 through 2009), by a total of 8.8% (5.4 million persons).

In 2020, young people under the age of 20 accounted for an 18 % share of Germany's population. The population of working age (in the present context: 20 through 64 years of age) accounted for 60 % of the total population, and the senior population (65 years of age and older) accounted for 22 %. About 7 % of the population were elderly – i.e., 80 years of age or older.

[26] The text presented in this chapter has been taken, with minor changes, from the Datenreport 2021 (2021 Data report) of the Federal Statistical Office (https://www.destatis.de/DE/Service/Statistik-Campus/Datenreport/Downloads/datenreport-2021.pdf?__blob=publicationFile). As far as the data themselves are concerned, however, more-recent data of the Federal Statistical Office have been used (https://www-genesis.destatis.de/genesis/online).

According to the current 2017/ 2019 mortality table, the life expectancy of male newborns was 78.6 years and that of female newborns was 83.4 years. In addition, the life expectancies for older people have increased sharply.

2.3 Economic development

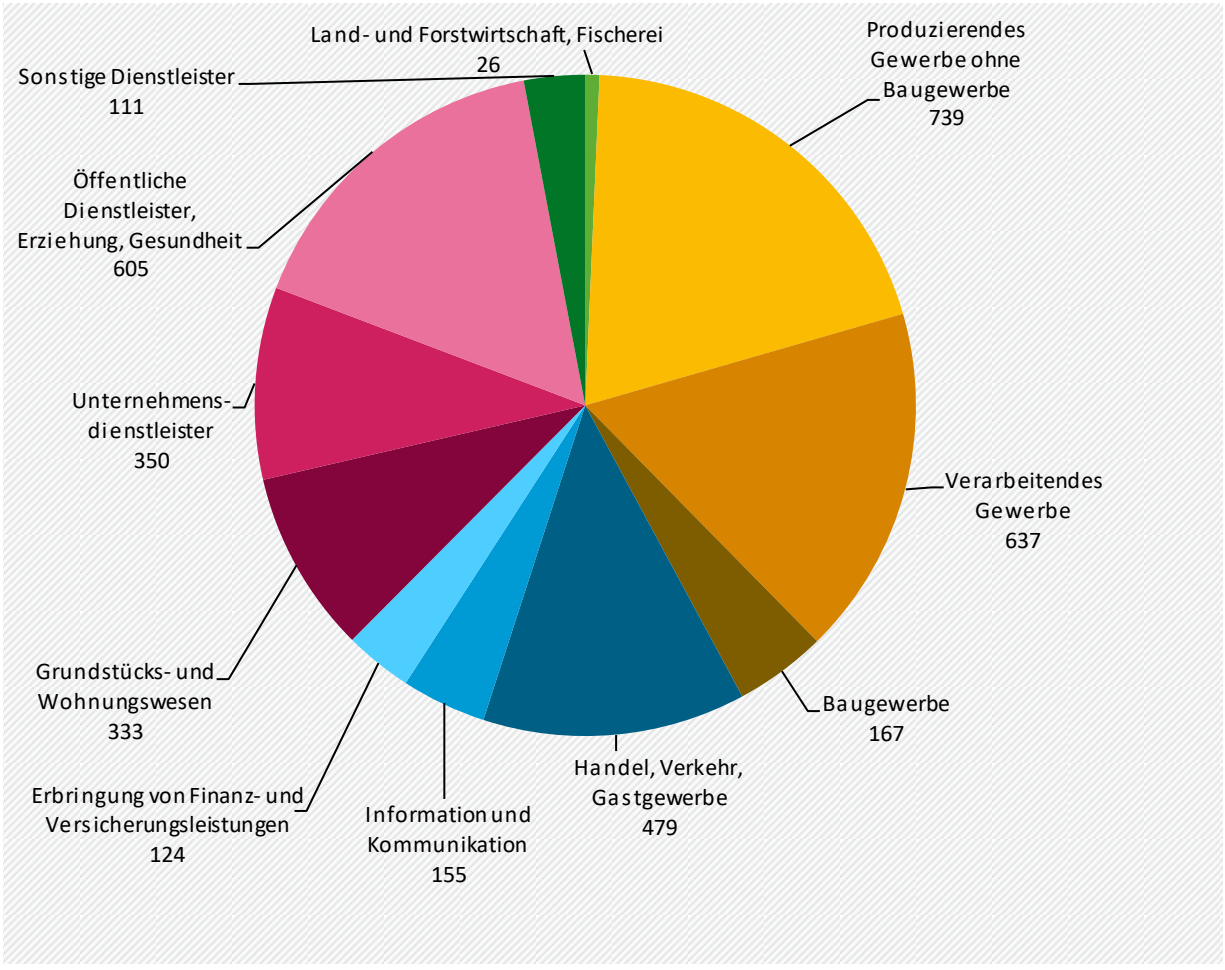
Germany's gross domestic product in 2020 was 3,405.43 billion euro. As a result of the coronavirus pandemic, it was about 2 % lower than it was in the previous year, however. The per-capita gross domestic product in 2020 was 40,950 euro.[27]

In its 2022 annual projection (Jahresprojektion 2022), the federal government forecasts 3.6 % growth for the price-adjusted gross domestic product.

The following figure shows the various economic sectors' contributions to gross value added.

Bruttowertschöpfung in Deutschland im Jahr 2020

nach Wirtschaftsbereichen, in jeweiligen Preisen (Mrd. EUR)*



* nominal/preisbereinigt

Quelle: © Statistisches Bundesamt (Destatis), 2022 | Stand: 13.10.2022 / 09:07:41

[27] German Federal Statistical Office (Statistisches Bundesamt 2021) https://www-genesis.destatis.de/genesis/online

Figure 2: Gross value added in Germany in 2020; Source: Statistisches Bundesamt (2020), own figure[28]

In 2020, employment in Germany was down by an average of about 477,000 persons. Large-scale reliance on short-time work, as a stopgap measure, shored up employment and prevented even-greater job losses. Because they faced a general shortage of skilled workers, companies eagerly accepted short-time work as an option for retaining their skilled staff. On a yearly average, unemployment grew by 429,000, to an average of 2.7 million persons. The unemployment rate grew by 0.9 percentage points, to 5.9 percent. During the same period, Germany was able to decrease its debt-to-GDP ratio from 82.3 to 59.6 percent, thanks to strong, continuous growth, and to stability-oriented economic and financial policies. In 2019, it met the Maastricht debt criteria, for the first time since 2002.

The coronavirus pandemic pushed the German economy into one of the most severe recessions it had experienced in decades. According to the Federal Statistical Office's preliminary results of its annual accounts, Germany's price-adjusted GDP decreased by 3.7 percent in 2020. By contrast, the Office's projection for the year had forecast a price-adjusted increase of 1.1 percent. Following a massive downturn in 2020, likely amounting to 7.2 percent, the euro area's overall economic output in 2021 is expected to have increased markedly (+4.3 percent), but not to the extent that would constitute a full recovery. In the wake of this first rapid, partial recovery, the German economy is gradually emerging further from the crisis. Its economic output is not expected to return to its pre-crisis level until the middle of 2022, however.

In 2020, Germany exported goods and services totalling 1,464.78 billion euro in value, and imported goods and services worth 1,273.13 billion euro. These sums combine into a net-export balance of 191.65 billion euro.

2.4 Geography and land use

The total area of Germany was 357,587 km² in 2020. Agricultural land accounted for a total of about 50.6 % (180,934 km²). The area under forest in 2020 accounted for a land share of nearly 29.8 % (106,666 km²). Among the areas allocated to the four overarching use types – settlement, transport, vegetation and waters – the area taken up by waters is the smallest in Germany. With an area of 8,194 km², it accounts for a share of slightly more than 2.3 % of the country's total area.[29]

[28] translation: title = Gross value added in Germany in 2020, by economic sector, in current prices (billion euros); Produzierendes Gewerbe ohne Baugewerbe = manufacturing excluding construction; Verarbeitendes Gewerbe = Manufacturing; Baugewerbe = Construction; Handel = Trade, Verkehr = Transport, Gastgewerbe = hotels and restaurants; Erbringung von Finanz- und Versicherungsdienstleistungen = Financial and insurance service activities; Grundstücks- und Wohnungswesen = Real estate, renting and business activities; Unternehmensdienstleister = Business service activities; Öffentliche Dienstleister, Erziehung, Gesundheit = Public service activities, education, health; Sonstige Dienstleister = Other service activities; Land- und Forstwirtschaft, Fischerei = Agriculture, forestry and fishing

[29] German Federal Statistical Office (Statistisches Bundesamt 2021) – Bodenfläche nach Art der tatsächlichen Nutzung – Fachserie 3 Reihe 5.1 – 2020. URL: https://www.statistischebibliothek.de/mir/receive/DEHeft_mods_00136613

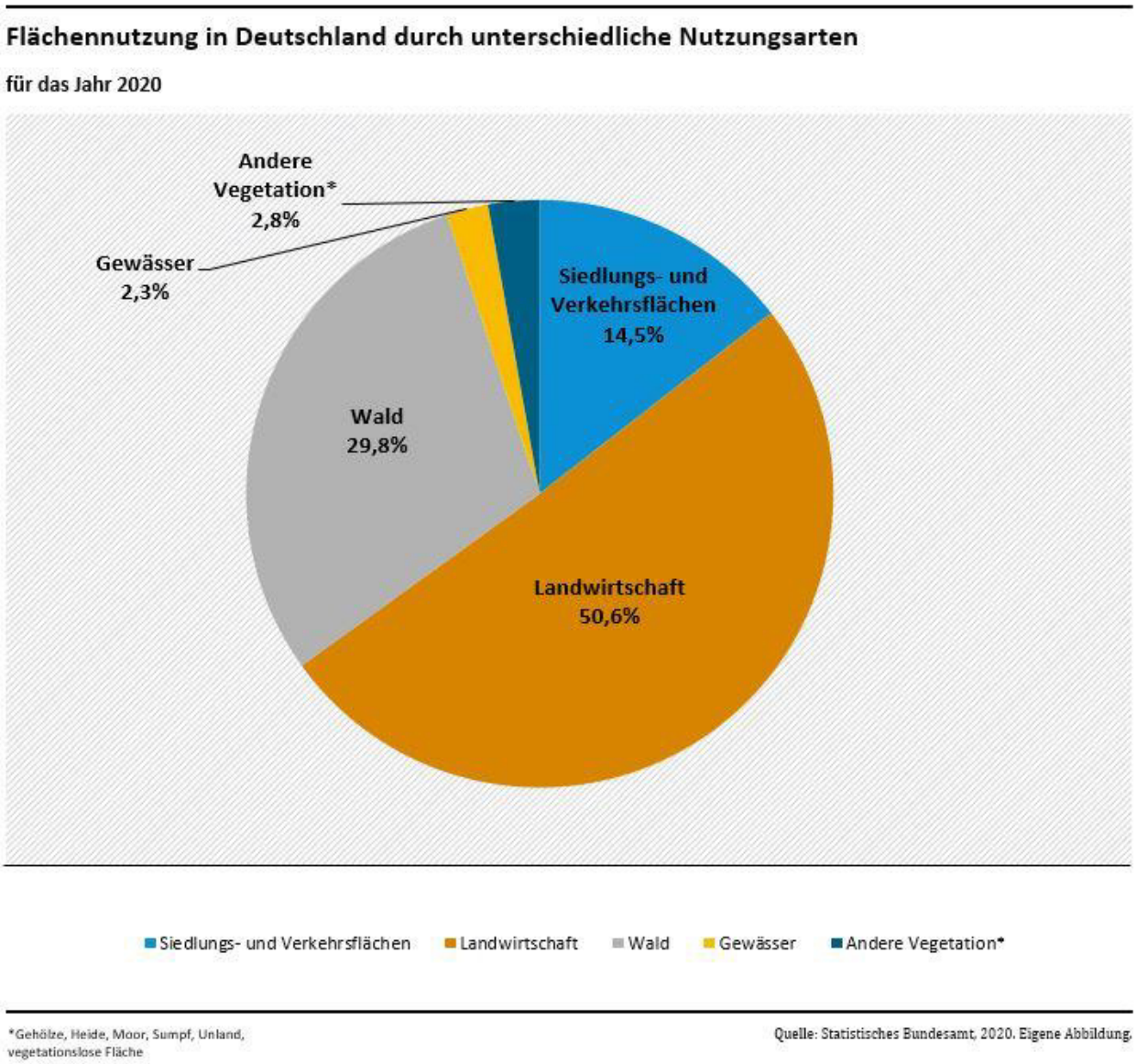


Figure 3: Land use in Germany in 2020; Source: Statistisches Bundesamt (2020)[30], own figure[31]

2.5 Climate and climate changes in Germany

Overall, Germany's climate is a warm-temperate rainy climate typical for middle latitudes. The average annual temperature for the period 1961 – 1990, for the area between the isle of Sylt and the Zugspitze (Germany's highest peak), was 8.2 °C. In the period 1991 – 2020, it increased to 9.3°C. An average of 1544 hours of sunshine was recorded in the period 1961 – 1990, and an average of 1665 hours was recorded in the period 1991 – 2020. Throughout the entire year, predominantly westerly winds bring damp air masses from the

[30] German Federal Statistical Office (Statistisches Bundesamt) – Genesis Online: https://www-genesis.destatis.de/genesis/online

[31] translation: title = Land use in Germany by different types of use - for the year 2020 (in percent); Siedlungs- und Verkehrsflächen = Settlement and traffic areas; Landwirtschaft = agriculture; Wald, Gewässer = forest, water bodies; Andere Vegetation (Gehölze, Heide, Moore, Sumpf, Unland, vegetationslose Fläche) = other vegetation (shrubberies, heath, moor, swamp, wasteland, vegetation-free area)

Atlantic, and provide precipitation of 789 l/m^2 per year. The oceanic influence on Germany's climate ensures that the country's winters are mild and its summers are not overly hot.[32]

Deutscher Wetterdienst (DWD), Germany's National Meteorological Service, has been observing weather and climate for over 150 years. Since 2005, the DWD has been systematically digitalising historical weather records, in order to produce a database that can usefully complement its fund of daily, digital weather data – and thereby enhance the reliability of the information the service provides. The emergence of weather services led to the development of a unified (at least partially unified) observation network that produces measurements that can be compared on an inter-site basis.

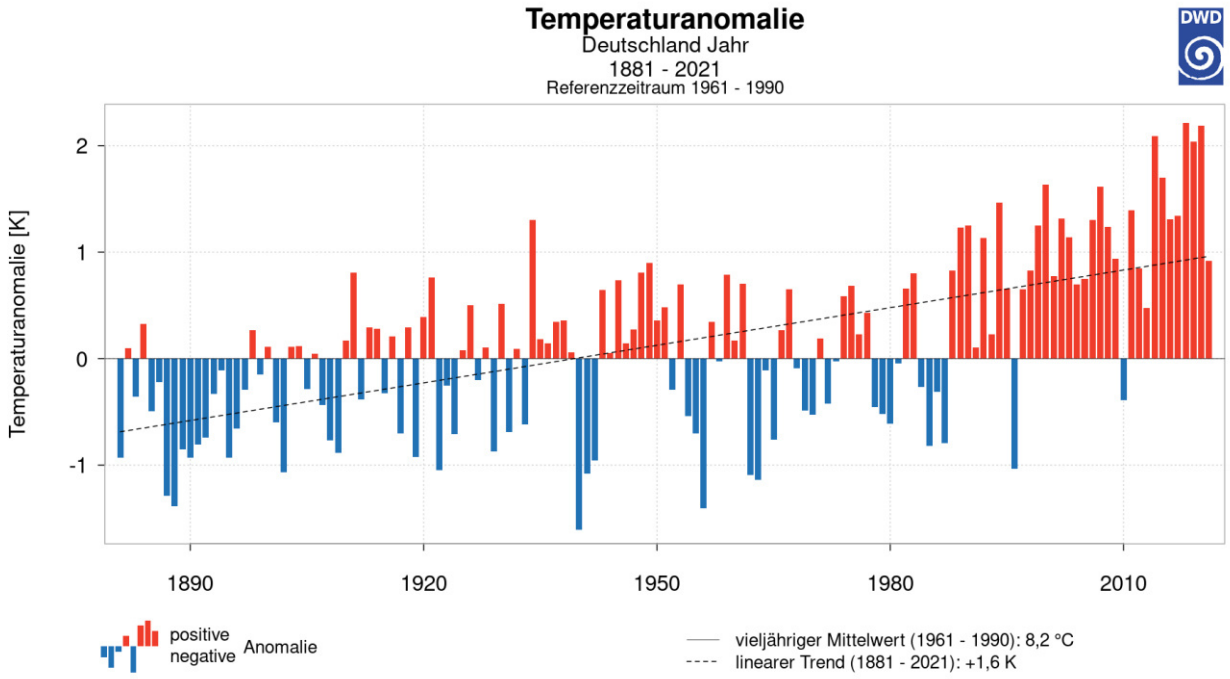


Figure 4: Annual average temperature in Germany; Source: Deutscher Wetterdienst (2022)[33,34]

From 1881-2021, the annual mean of Germany's air temperature rose by 1.6 °C (linear trend). And this temperature trend has accelerated in recent decades. With an average temperature of 9.8 °C, the decade 2011-2020 was 2 °C warmer than the first 30 years of the observation period, 1881-1910.

The largest increase since 1881, 1.7 °C, has occurred in the Westphalian Lowland, in the low mountain ranges west of the Rhine River and in the Upper Rhine Graben. The smallest increase, 1.2 °C, has occurred in the northeast German plain. The year 2018 was recorded as the warmest in Germany since 1881. Thirteen of the 20 warmest years have occurred in the 21st century.

[32] German Meteorological Service (Deutscher Wetterdienst 2022)
[33] German Meteorological Service (Deutscher Wetterdienst 2022): Nationaler Klimareport; 6. überarbeitete Auflage, Deutscher Wetterdienst, Deutschland, 53 pages. ISBN 978-3-88148-537-1. https://www.dwd.de/DE/leistungen/nationalerklimareport/report.html
[34] translation: Temperaturanomalie – Deutschland Jahr 1881-2021 – Referenzzeitraum 1961 – 1990 = emperature anomaly - Germany year 1881-2021 - reference period 1961 - 1990; Temperaturanomalie [K] = temperature anomaly [K]; Anomalie = Anomaly; vieljähriger Mittelwert = multi-year mean; linearer Trend = linear trend

On average, Germany receives 789 litres per square metre (l/m^2) of precipitation per year. Precipitation varies widely over time and by area, however: The wettest-ever year since 1881, averaged over all of Germany, was 2002, with precipitation of 1,018 l/m^2. The driest year, with 551 l/m^2, was 1959. Since 1881, Germany's annual average precipitation – with fluctuations, including strong fluctuations, from year to year, or from decade to decade – has increased by 63 l/m^2. Since the 1961–1990 reference period, it has increased by nearly 8 l/m^2.

Germany's warmest regions experience the lion's share of the country's heat waves. In the period 1961–1990, the average number of hot days in the Upper Rhine Graben, the Westphalian Lowland and the east German basin and hills, ranged from six to nine per year.

In the period 1991–2020, that figure has grown to an average of twelve, while in the upper Rhine lowlands it has grown to 16 days per year. In the Alpine foreland and the Alps, nine and four hot days per year, respectively, are the norm. Those numbers are more than double (Alpine foreland) and more than five times (Alps) the corresponding figures during the reference period 1961–1990.

A detailed overview of projected future climate changes in Germany is provided in Chapter 7.3, as well as in the section on analysis of climate impacts and risks (2021)[35].

2.6 Energy

2.6.1 Energy consumption by sectors and fuels

Primary energy consumption (until 2021)

Primary energy consumption is determined as 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 fuels.

Primary energy consumption has been decreasing in Germany since the beginning of the 1990s. This effect is to some extent 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 efficiency of 100 percent) leads to lower primary energy consumption by squeezing out other energy sources with a lower conversion efficiency. It also is due to real efficiency increases, however.

In 2021, primary energy consumption, pursuant to provisional data, amounted to 12,413 petajoules (PJ), which represents an increase of 4.4 % over the previous year.[36] The quantity of primary energy used in 2020 (11,895 PJ) in Germany was the lowest for all years since 1990. The reasons for the low consumption included the recession and a sharp reduction in travel as a result of the global coronavirus pandemic. And primary energy consumption in 2021, in spite of being markedly higher than it had been in 2020, was the second lowest seen in all years since 1990. Under Germany's "Energy Efficiency Strategy 2050," the federal government is aiming to reduce the country's primary energy consumption by 30 % by 2030, and by 50 % by 2050, with respect to 2008 levels.

[35] https://www.umweltbundesamt.de/publikationen/KWRA-Zusammenfassung

[36] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022): Auswertungstabellen zur Energiebilanz Deutschland. Daten für die Jahre 1990 bis 2021. https://ag-energiebilanzen.de/daten-und-fakten/auswertungstabellen/

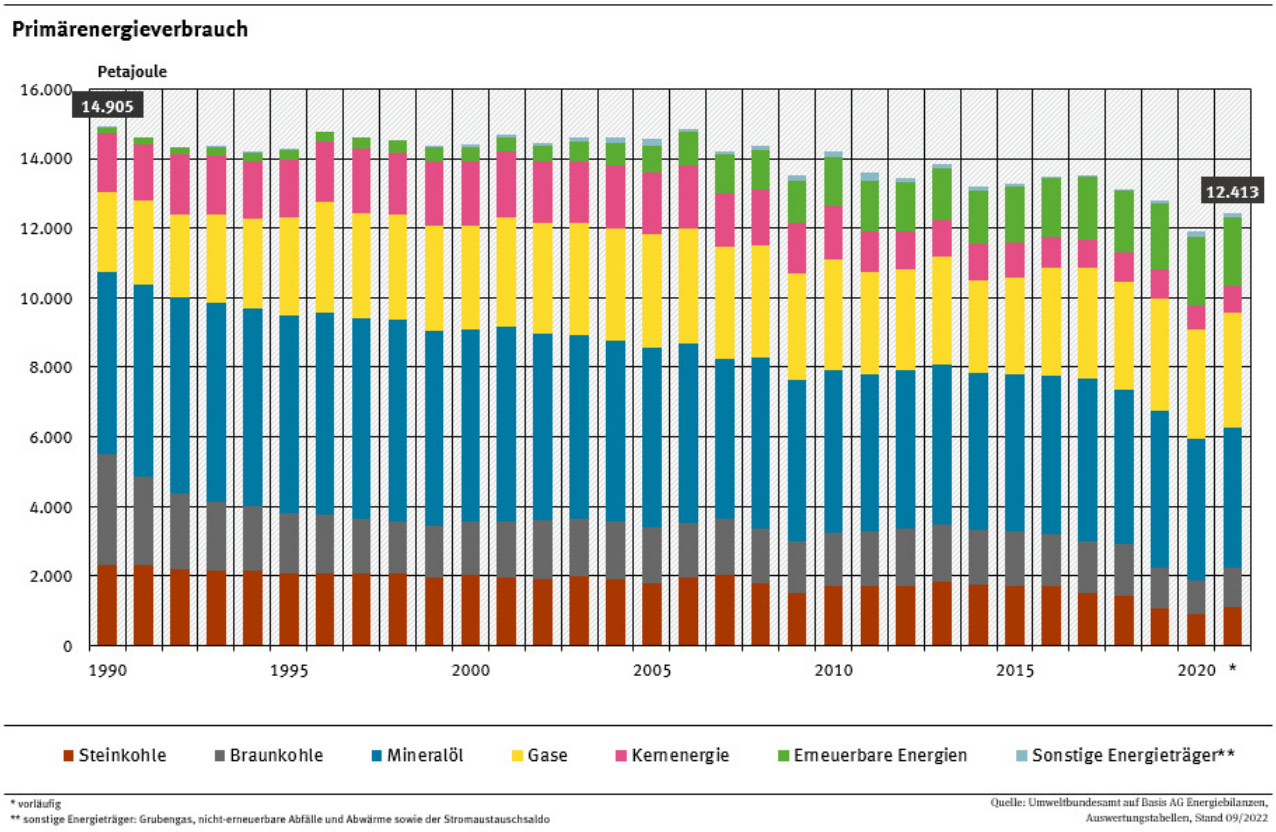


Figure 5: Primary energy consumption; Source: Working Group on Energy Balances (AGEB) (2022)[37,38]

Final energy consumption (until 2021)

Final energy consumption has hardly decreased at all in Germany since the beginning of the 1990s. While energy efficiency continues to grow, and more and more energy is being saved, economic growth and increases in consumption have prevented a more-pronounced real decrease in consumption. In the short term, such as over the course of a single year, the weather, which influences heat-energy use, has a major impact on consumption trends.

The sectoral structure of final energy consumption has changed: The industry sector's share of total final energy consumption decreased from 31.4 % in 1990 to 29.0 % in 2021. A similar development occurred in the sector trade, commerce and services; its share of total final energy consumption decreased slightly, from 18.6 % to 16.0 %. The share for private households increased from 24.9 % to 27.8 %, while that for the transport sector increased from 25.1 % to 27.1 %. That said, the transport sector's energy consumption was especially low in 2021, due to the impacts of the coronavirus pandemic. In 2019, the year prior to the pandemic, its share was 30.3 %.

[37] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[38] translation: title = Primary energy consumption; categories = hard coal, lignite, mineral oil, gases, nuclear energy, renewable energy, other energy sources (mine gas, non-renewable waste and electricity trading balance)

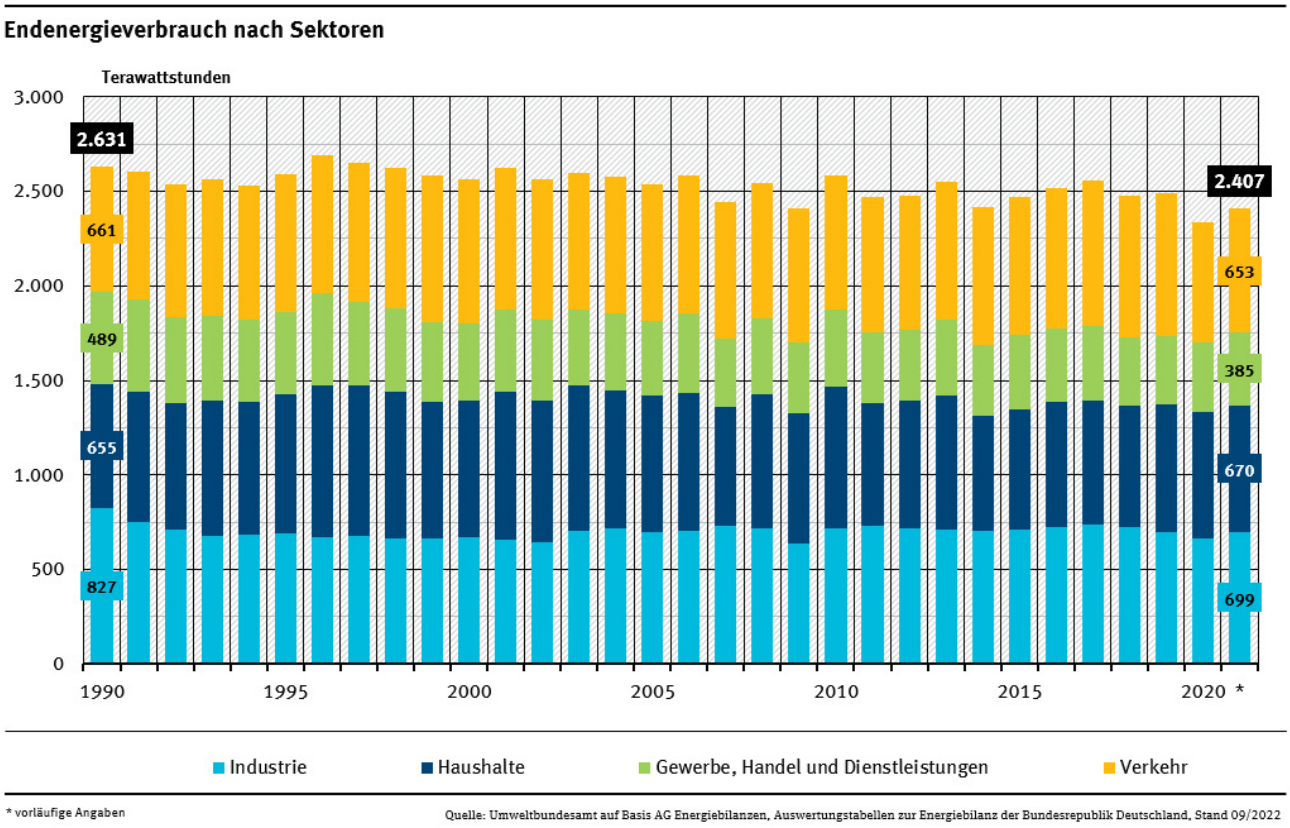


Figure 6: Final energy consumption by sectors; Source: Working Group on Energy Balances (2022) [39,40]

Final energy consumption in the various sectors, by fuels (until 2021)

In 2021, petroleum accounted for a 33.3 % share of final energy consumption. In 2019, the year prior to the pandemic, its share was 37.8 %. Natural gas had a 25.9 % share in 2021, while electricity had a 20.6 % share. A total of 41 % of the electricity used in 2021 was generated via renewable energies. Renewable fuels, in the form of biomass for heating and as motor fuels, accounted for a share of 8.8 %. Renewable energies' overall share of final energy consumption in 2021 was 19.7 % (determined on the basis of the provisions of EU Directive 2018/2001). The contributions of coal and district heating were nearly the same; each had a share of nearly 5 % of final energy consumption. Other energy sources / fuels, such as waste and waste heat, accounted for a share of 0.6 %.

[39] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[40] translation: title = Final energy consumption by sector; y-axis= terrawatt hours, categories =industry, households; commercial/institutional, transport

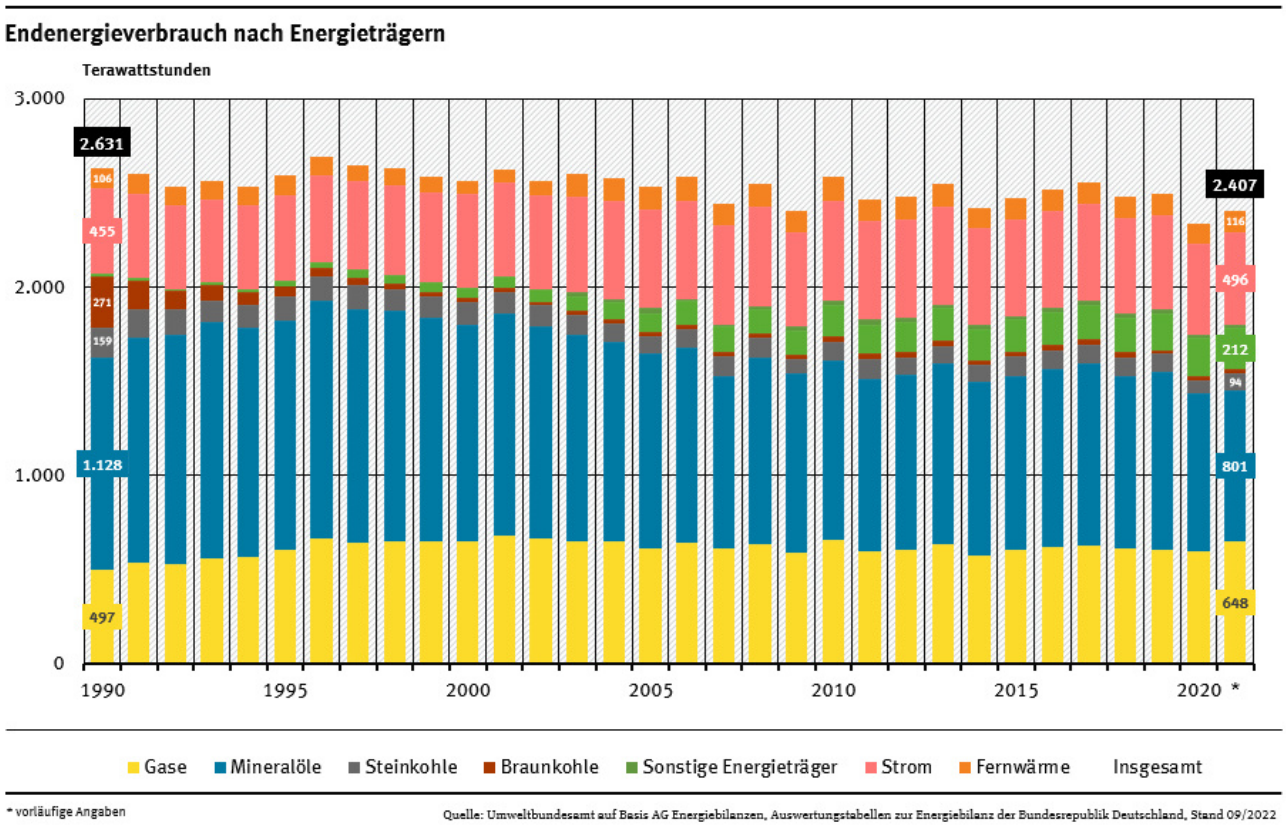


Figure 7: Final energy consumption by fuels / energy sources; Source: Working Group on Energy Balances (2022) [41,42]

In the **industry** sector, final energy consumption decreased noticeably since 1990. This trend was due mainly to the decline of industry in the new German Länder between 1990 and 1993. Industry's final energy consumption has remained largely the same since the 1990s; it fluctuates around a value of 700 TWh. Process heat accounted for about two thirds of industry final energy consumption in 2020. Mechanical energy – for example, for operation of motors and machines – accounted for somewhat more than one fifth of consumption. Space heating, on the other hand, accounted for only a small share (5.8 %). The most important fuels / energy sources in 2021 were natural gas (32 %), electricity (30 %) and hard coal (13 %).

In the **transport sector**, final energy consumption increased continuously between 2009 and 2017 – from 706 to 768 TWh. Since 2013, that sector has been the one with the highest energy consumption, ahead of the industry sector. In 2020, as a result of the impacts of the coronavirus pandemic, transports decreased sharply, and final energy consumption in this sector thereby decreased as well. To date, over 90 % of the fuels used in the transport sector are petroleum-based. Biofuels and electricity (from renewables, to some extent) are still playing minor roles, with most-recent (2021) shares of 5.9 % and 0.9 %, respectively. Nearly all of the energy used in the transport sector is used to generate mechanical energy. On average, less than half of the energy consumed in internal combustion engines is actually used for mobility; a large share is lost as waste heat.

[41] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[42] translation: title = Final energy consumption by fuels / energy sources; y-axis = terrawatt hours; categories = gases, mineral oil, hard coal, lignite, other energy sources; electricity, district heating, total; footnote = *preliminary data

Energy consumption by **private households** reached its maximum, about 800 TWh, in 1996. Consumption in this sector has been tending to decrease since then, and it has fluctuated around a value of 650 TWh in recent years. In 2020, space heating accounted for about 68 % of energy consumption by households. The corresponding share in 1996 was higher than 78 percent; energy consumption for heating decreased disproportionately in the 1990s, even though the per-capita living space in Germany has grown since the 1990s. Natural gas accounts for the largest share of households' final energy consumption, 42.1 %, followed by electricity at 18.9 %. Renewable energies accounted for 41 % of the electricity generated in Germany in 2021. Also, renewables-based heat and district heat are increasingly being used in this sector.

The **trade, commerce and services** sector, with most-recent energy consumption of about 385 TWh, is the smallest of the four consumption sectors. At the beginning of the 1990s, consumption in this sector was considerably higher, at 490 TWh. Energy consumption in the sector decreased until the mid-2000s. In 2007, it went considerably below 400 TWh for the first time, and reached 363 TWh. Since then, the sector's annual consumption has ranged between 360 and 410 TWh, with a slightly falling trend overall. In the short term, energy consumption in this sector, like that of private households, depends on weather-related heating demand. This is not surprising in that space heating accounts for fully half of the sector's final energy consumption. Electricity accounts for a 37.4 % share (most recent figure) of the sector's final energy consumption – a larger share than is found in any of the other sectors. This indicates that the sector requires especially large quantities of energy for lighting and mechanical energy.

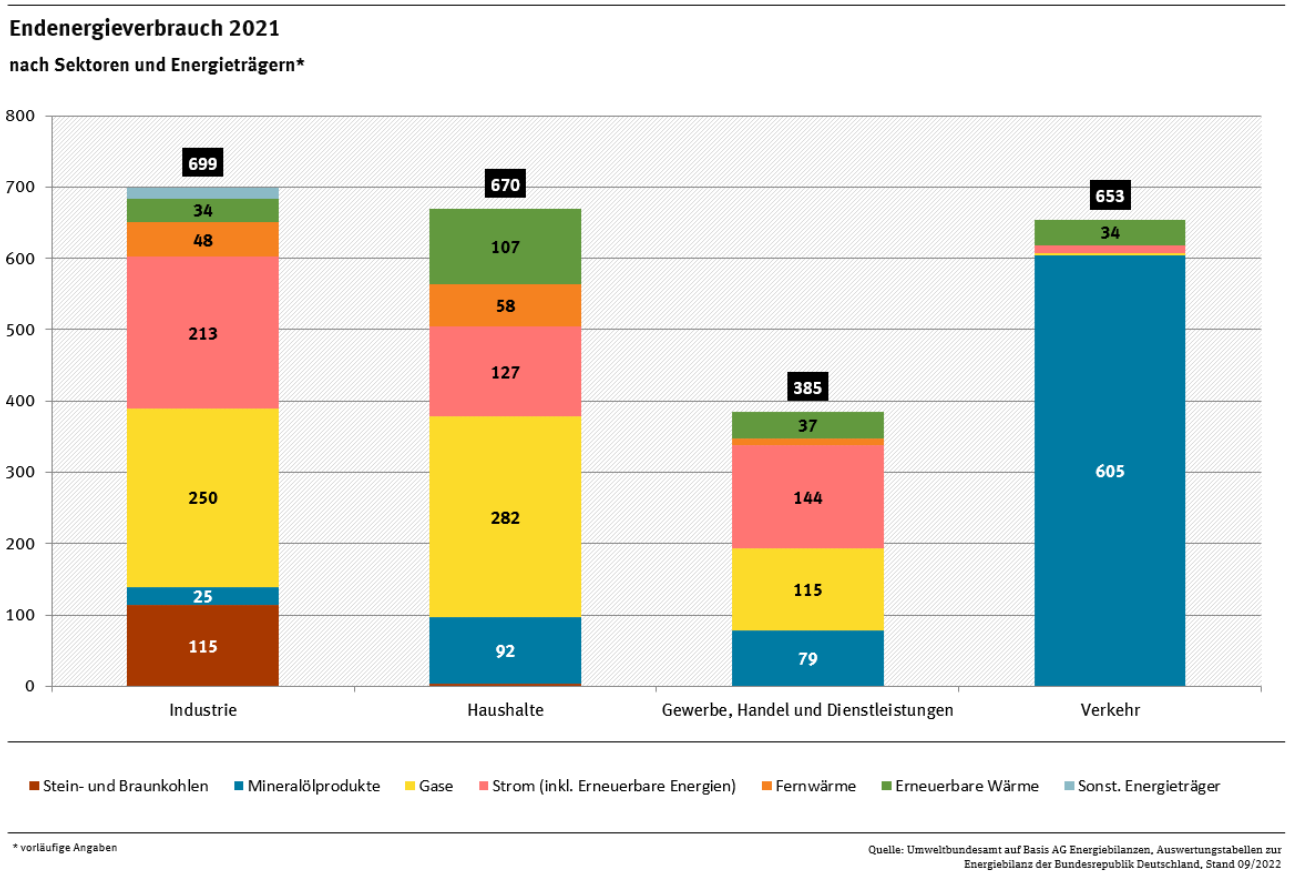


Figure 8: Final energy consumption in 2021, by sectors and fuels / energy sources; Source: Working Group on Energy Balances (2022) [43, 44]

2.6.2 Electricity generation by fuels / energy sources

In 2021, gross electricity generation in Germany amounted to 583.5 TWh, pursuant to provisional data. When this is combined with the net balance resulting from electricity exchange with other countries, a gross domestic electricity consumption[45] of 565 TWh results.[46]

In the 1990s, gross electricity consumption and gross electricity generation decreased for a time, and then increased through the year 2005. In subsequent years, the two figures exhibited diverging trends.

Since 2007, gross electricity consumption has decreased almost continuously (except in the recession years 2009 and 2020, when downturns were followed by renewed increases). Gross electricity consumption in 2021 was 8.5 % below that of the year 2007.

[43] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[44] translation: title = Final energy consumption 2021 – by sector and fuels / energy sources; bas = Industry; households; commercial/institutional; transport; categories = hard coal and lignite, mineral oil products, gases, electricity (incl. renewable energies), district heating, renewable heat, other energy sources; footnote = *preliminary data

[45] Domestically consumed quantity of electricity, including network losses and own consumption

[46] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022): Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2021 (in TWh) Deutschland insgesamt (electricity generation by fuels / energy sources (electricity mix), from 1990 through 2021 (in TWh), for Germany as a whole). Last revision: 16 September 2022. https://ag-energiebilanzen.de/daten-und-fakten/zusatzinformationen/

Gross electricity generation, by contrast, continued to increase after the year 2007, reaching a maximum of 647 TWh in 2017. A total of 8.1 % of the electricity generated in 2017 was exported abroad. That development was promoted especially by lignite-fired power plants with relatively low generation costs. Generation at such plants was not drawn down to the same degree in which electricity generation from renewable energy sources was increased. With respect to the year 2017, Germany's gross electricity generation has decreased considerably; in 2021, it was 9.8 % below its level in 2017. In 2021, the net share of electricity that was exported abroad amounted to only 3.2 % of gross electricity generation.[47]

The most important consumption sectors on the level of final energy consumption include industry (42.9 % of total electricity consumption in 2021), the sector trade, commerce and services (29 %) and private households (25.6 %). Transport accounts for only 2.5 % of electricity consumption. Through 2021, industry and private households each reduced their electricity consumption by about 10 % with respect to their maxima, which were reached in 2007 and 2010, respectively. Electricity consumption in the trade, commerce and services sector reached its maximum in 2016. Since then, it has decreased by 4.6 %.[48]

The various relevant fuels' / energy sources' shares of gross electricity generation have shifted markedly since 1990. Most notably, renewable energies' share of electricity generation has increased sharply, from 3.6 % to 40.1 %, and the combined share for lignite, hard coal and nuclear energy dropped from 84.4 % in 1990 to 40 % in 2021. In 2019, for the first time ever, renewable-energy power plants generated more power than all of the country's lignite- and hard-coal-fired power plants combined. In 2020 and 2021, they even generated more power than all of the country's coal-fired and nuclear power plants combined. During the same period, natural gas power plants' share of electricity generation increased from

[47] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022): Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2021 (in TWh) Deutschland insgesamt (electricity generation by fuels / energy sources (electricity mix), from 1990 through 2021 (in TWh), for Germany as a whole). Last revision: 16 September 2022. https://ag-energiebilanzen.de/daten-und-fakten/zusatzinformationen/

[48] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2022): Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2021 (in TWh) Deutschland insgesamt (electricity generation by fuels / energy sources (electricity mix), from 1990 through 2021 (in TWh), for Germany as a whole). Last revision: 16 September 2022. https://ag-energiebilanzen.de/daten-und-fakten/zusatzinformationen/

6.5 % to 15.6 %.[49]

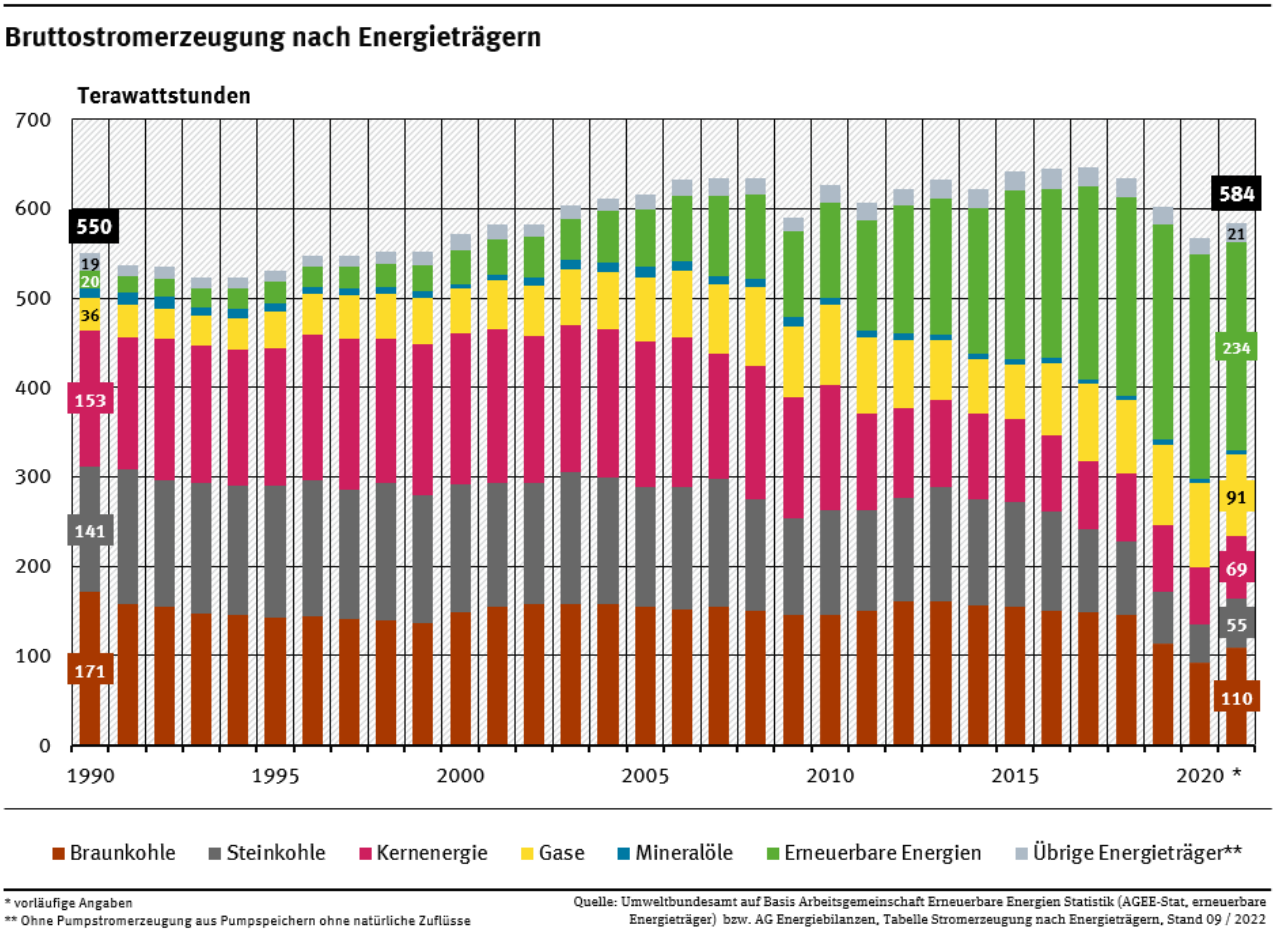


Figure 9: Gross electricity generation by fuels / energy sources; Source: German Environment Agency, on the basis of Working Group on renewable energy statistics (Arbeitsgemeinschaft Erneuerbare Energien Statistik – AGEE-Stat; renewable energy sources)[50] and Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen – 2022a, fossile Energieträger)[51,52]

In 2021, the largest contribution to electricity generation from renewable energies, 39 %, came from onshore wind energy. Offshore wind energy accounted for a contribution of 10 % (24 TWh) to gross electricity generation. Biomass (biogenic solid and liquid fuels; biogas, sewage gas and landfill gas; and biogenic fractions of waste) accounted for 21 % (50 TWh) of renewables-based gross electricity generation, or about as much as the share for photovoltaic systems (49 TWh).[53]

[49] German Environment Agency (Umweltbundesamt), on the basis of German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen, AGEB 2022): Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2021 (in TWh) Deutschland insgesamt (electricity generation by fuels / energy sources (electricity mix), from 1990 through 2021 (in TWh), for Germany as a whole). Last revision: 16 September 2022. https://ag-energiebilanzen.de/daten-und-fakten/zusatzinformationen/ (fossil fuels)

[50] https://www.erneuerbare-energien.de/EE/Navigation/DE/Service/Erneuerbare_Energien_in_Zahlen/Aktuelle-Informationen/aktuelle-informationen.html

[51] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[52] translation: title = Gross electricity generation by energy source, y-axis = terawatt hours; categories = lignite, hard coal, nuclear energy, gases, mineral oils, renewable energies, othe energy sources; footnotes = * preliminary data, ** without pumped-storage power generation without natural inflows

[53] German Environment Agency (Umweltbundesamt), on the basis of German Working Group on renewable energy statistics (Arbeitsgemeinschaft Erneuerbare Energien Statistik)

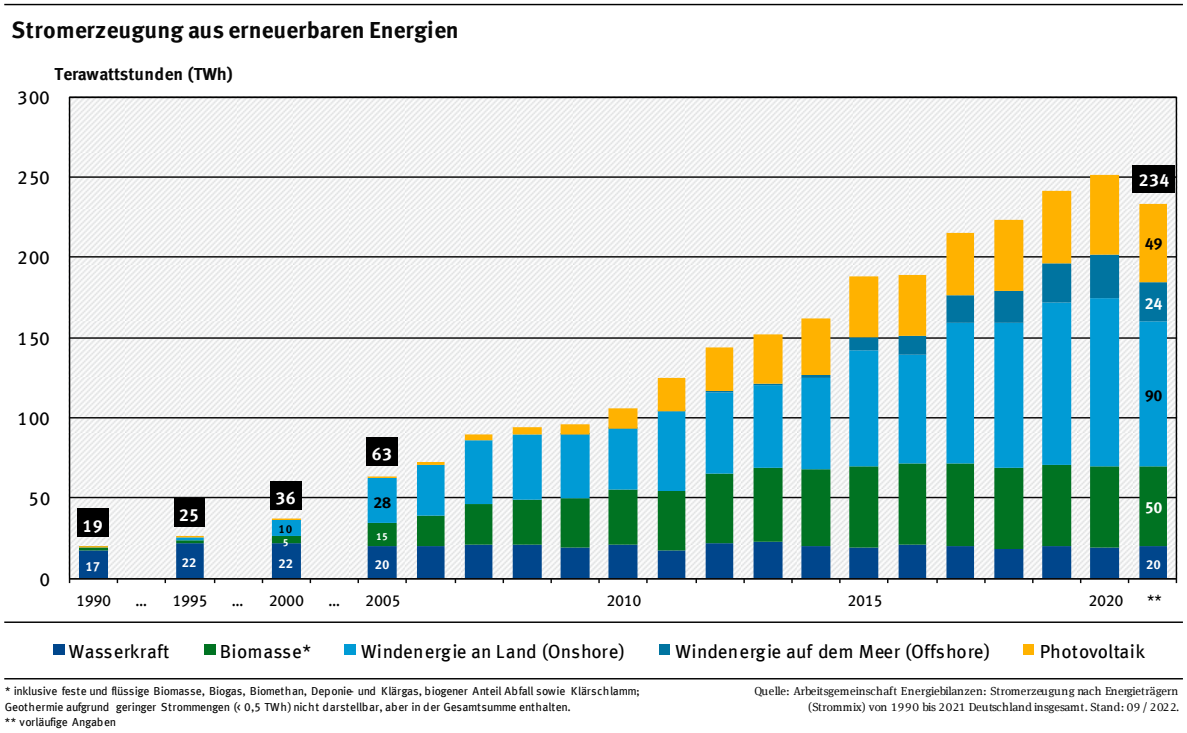


Figure 10: Electricity generation from renewable energy sources; Source: Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): Stromerzeugung nach Energieträgern (Strommix) von 1990 bis 2021 Deutschland insgesamt (electricity generation by fuels / energy sources (electricity mix), from 1990 through 2021, for Germany as a whole). Last revised: 09 / 2022[54,55]

[54] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[55] translation: title = Power generation from renewable energy sources; y-axis = Terrawatt hours (TWh); categories = Hydropower, Biomass, Onshore wind energy, Offshore wind energy, Photovoltaics

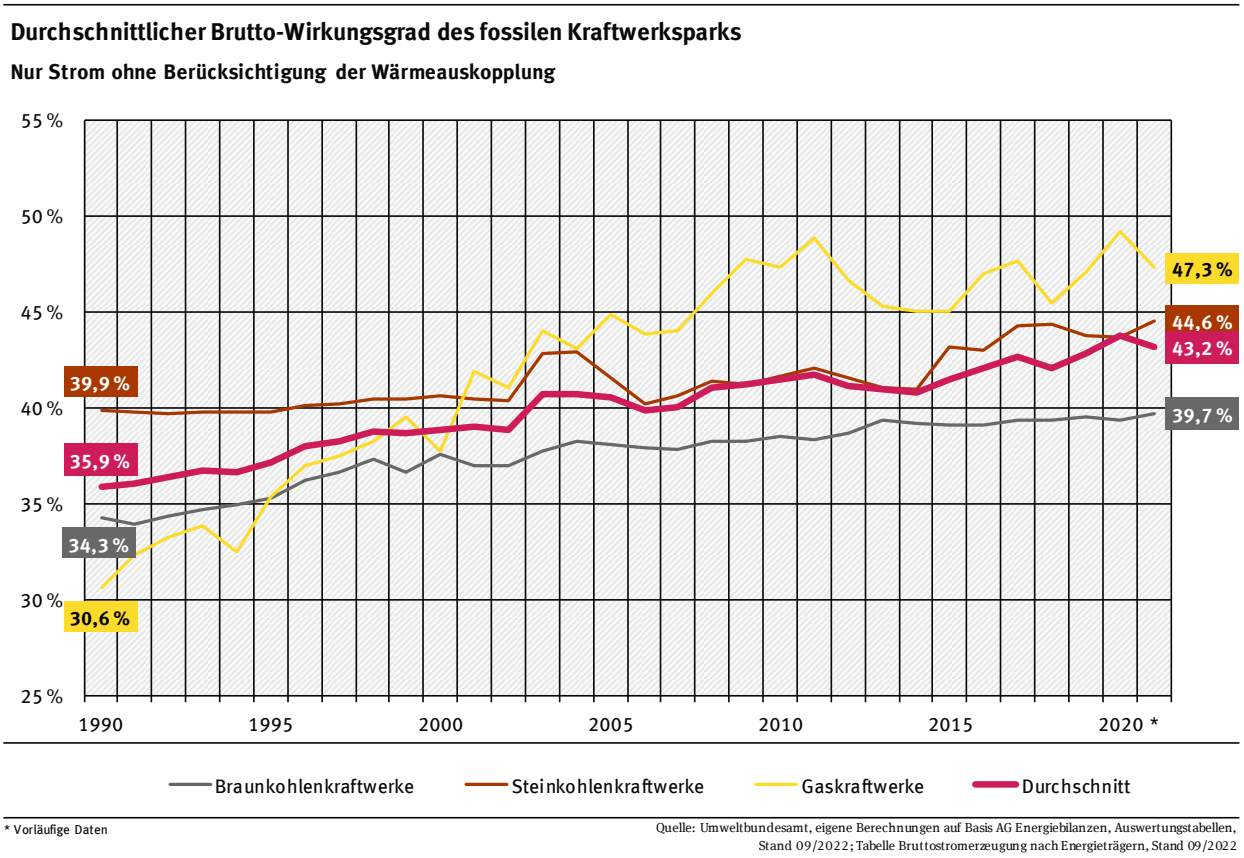


Figure 11: Average gross efficiency of fossil-fuel power plants (Source: Working Group on Energy Balances 2022) [56,57]

In recent decades, the market conditions for fossil-fuel power plants have changed – in some cases, considerably. This trend has led to modernisation of some power plants, to decommissioning of old power plants and to some new construction of state-of-the-art power plants. These changes are reflected in higher average plant efficiencies, over all of the fuels involved. Efficiencies increased especially sharply in the case of gas power plants, and to a lesser degree for lignite and hard-coal power plants (cf. Fig. 10). On a quantity-weighted average, efficiency increased from 35.9 % to 43.7 %.

2.6.3 Energy prices

Prior to 2022, when energy prices increased suddenly and sharply, for crisis-related reasons, prices had remained relatively stable, in spite of some fluctuations. For several years (until 2019), energy costs for the general public had not risen at all – on average, and as seen from a macroeconomic perspective. End consumers spent more for final energy overall in 2019 than they had in the previous year. Nonetheless, expenditures on final energy, as a share of economic output, decreased in comparison to their level in the previous year. At 6.5 percent, they even reached their lowest value since 2002. This occurred in that the

[56] Website of the German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen): URL: https://ag-energiebilanzen.de/

[57] translation: title = Average gross efficiency of fossil-fuel power plants - Electricity only without consideration of heat extraction; categories = lignite-fired power plants, hard-coal-fired power plants, gas-powered power plants, average; footnote = *preliminary data

increase in energy expenditures was more than offset by an increase in the country's nominal gross domestic product.

For companies facing especially high electricity and energy costs, cost-relief provisions, aimed at safeguarding competitiveness, provided significant reductions of statutory electricity-price / energy-price components, under certain conditions.[58]

Energy resources, and emission certificates

The prices for energy resources such as oil, natural gas and hard coal have risen since the beginning of the new millennium. The reasons for this include growing international demand. In 2008, as a result of the global economic crisis that occurred in that year, prices fell temporarily by over 30 %, only to begin climbing again sharply until 2012. Until 2015, prices for all important energy resources then exhibited a falling trend. From 2016 through 2018, they increased again, and in 2019 they fell again.

The situation in 2020 was as follows: The price per barrel of oil (for the crude-oil benchmark West Texas Intermediate (WTI)) averaged $39.2/bbl in 2020. The German border-crossing price for natural gas decreased in 2020, with respect to the previous year, to 3,410 € / TJ. The average annual price for imported thermal coal dropped to 64 € / t coal equivalent (tce).[59]

The prices for CO_2 emission allowances, within the European emissions trading scheme (EU-ETS), increased from 5.8 € per tonne of CO_2 equivalent in 2017 to 24.4 € per tonne of CO_2 equivalent in 2020.

Price trends at the international and European levels are key drivers for energy prices and energy-cost trends for end consumers in Germany.

Electricity

The upward trend that began in 2016, in electricity prices in exchange-based power trading, initially continued in 2018. On the European Energy Exchange (EEX), the price for subsequent-year deliveries (baseload, year future) increased, on a yearly average for 2018, and with respect to 2017, by a full 32 percent, to 44.20 € / MWh. In 2019, the price remained largely unchanged, and wound up at a yearly average of 48.06 € / MWh. Beginning in late summer 2019 – and, in part, as a result of the Covid-19 pandemic – prices on futures markets then dropped continuously, however.[60] Changes in wholesale prices affect end-consumer prices following a time lag.

Household prices in 2017 were at 29.86 euro cents per kWh. By 2020, they had increased to 32.06 euro cents / kWh (for consumption in the range 2,500 – 5,000 kWh / year, and including taxes and duties, as of the reporting date 1 April). Electricity prices also increased for non-household consumers.

[58] German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie 2021): Die Energie der Zukunft. Achter Monitoring-Bericht zur Energiewende (Eighth monitoring report on the energy system transformation); available at: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/achter-monitoring-bericht-energie-der-zukunft.pdf?__blob=publicationFile&v=32 [last checked on 14 Oct. 2022]

[59] German Federal Institute for Geosciences and Raw Materials (Bundesanstalt für Geowissenschaften und Rohstoffe 2021): Deutschland – Rohstoffsituation 2020. – 158 p.; Hannover.

[60] German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie 2021): Die Energie der Zukunft. Achter Monitoring-Bericht zur Energiewende (Eighth monitoring report on the energy system transformation); available at: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/achter-monitoring-bericht-energie-der-zukunft.pdf?__blob=publicationFile&v=32 [last checked on 14 Oct. 2022]

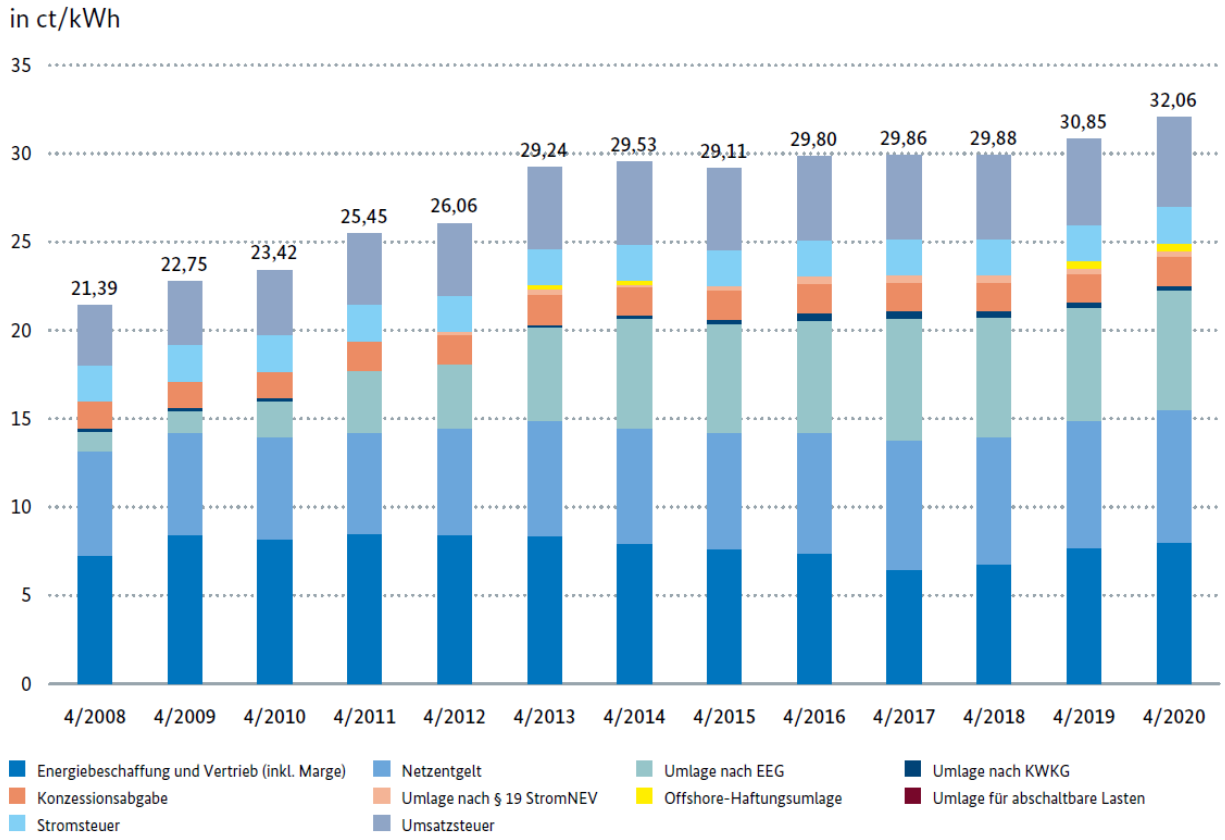


Figure 12: Electricity prices for household consumers; Source: Bundesministerium für Wirtschaft und Energie (Federal Ministry for Economic Affairs and Energy): Die Energie der Zukunft. Achter Monitoring-Bericht zur Energiewende (Eighth monitoring report on the energy system transformation) (last revision: 02/2021), auf Basis Bundesnetzagentur (BNetzA)[61,62]

For large consumers not eligible for preferential-rates provisions, and for purchase reductions of 24 GWh / year, the Federal Network Agency gives a range of 14.48 through 18.62 euro cent / kWh for 2020; with preferential rates, a reduction of up to 11.32 euro cent / kWh is available for the same purchasing profile.[63]

These electricity prices for commercial and industrial consumers do not apply for electricity-intensive companies, however. Subject to the fulfilment of applicable criteria, large electricity consumers can be eligible for several relief provisions pursuant to the Electricity Tax Act and the Renewable Energy Sources Act (EEG). As a result, electricity prices for such

[61] German Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz 2021) – Achter Monitoring-Bericht "Die Energie der Zukunft". URL: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/achter-monitoring-bericht-energie-der-zukunft.html

[62] translation: categories (by line, left, to right)) = Energy procurement and sales (incl. margin), grid fee, levy according to EEG, levy according to KWKG, concession fee, levy according to § 19 StromNEV, offshore liability levy, levy for disconnectable loads, electricity tax, VAT

[63] Cf. German Federal Network Agency, German Federal Cartel Office (Bundesnetzagentur, Bundeskartellamt 2021): Monitoringbericht 2020. Monitoringbericht gemäß § 63 Abs. 3 i. V. m. § 35 EnWG und § 48 Abs. 3 i. V. m. § 53 Abs. 3 GWB (Monitoring report pursuant to Section 63 (3) in conjunction with Section 35 Energy Industry Act (EnWG) and Section 48 (3) in conjunction with Section 53 (3) Competition Act (GWB)); available at: https://www.bundeskartellamt.de/SharedDocs/Publikation/DE/Berichte/Energie-Monitoring-2020.pdf?__blob=publicationFile&v=4 [last checked on 14 Oct. 2022]

consumers can, in some cases, be considerably lower. No statistical surveys of this consumption segment are carried out, however, and the actual prices involved cover a wide range.

Seen from a macroeconomic perspective, aggregated over all end consumers, expenditures for primary energy increased for the second time in a row in 2018, with respect to the previous year – by 9.7 percent, to 103 billion euro. Seen in the context of a ten-year comparison, they are at a mid-range level, however. The increase that occurred in 2018 was tied primarily to sharp increases in import prices for fossil resources, even as energy demand decreased slightly. As a result of consumption of imported fossil-based primary-energy fuels, energy costs increased from about 56.9 billion euro in 2016 to about 67.6 billion euro in 2018. But since import prices decreased markedly in 2019, this trend did not last, even though imports increased again (especially gas imports). All in all, the energy costs for consumption of imported fossil-based primary-energy fuels amounted to about 65.2 billion euro in 2019. As a result, the economy's expenditures for provision of primary energy decreased to 98.1 billion euro, or a level just slightly higher than the corresponding level of 2017 – and considerably below the average for the last ten years, 106.9 billion euro. In 2018, end consumers' expenditures for final energy increased from 217 to 221 billion euro. In 2019, they increased again, to 224 billion euro.[64]

2.6.4 Impacts on GHG emissions

Energy-related emissions are the primary component of Germany's GHG emissions, with a share of 83.5 %[65] in 2020. Energy-related emissions include greenhouse gases and air pollutants that are released via transformation of fuels into electrical and/or thermal energy (electricity and heat production). Energy-related emissions occur in connection with electricity and heat production in power plants. In the industrial sector, they occur via certain industrial processes. In the households / small consumers sector, energy-related emissions occur primarily via heating with fossil fuels. In the transport sector, energy-related emissions are released in the exhaust of internal combustion engines. Diffuse emissions from agriculture, abandoned landfills or mines, are not included among energy-related emissions.

In an industrialised country such as Germany, energy-related emissions of direct and indirect greenhouse gases are primarily influenced by the economic situation. Such emissions are strongly dependent on the mix of energy sources that is used, the efficiency and mode of operation of the fossil-fuel power-station fleet, the efficiency of other technologies that are used and – given the need for heating – weather conditions.

Initial provisional calculations and estimates by the German Environment Agency (UBA) indicate that total greenhouse gas emissions in 2021 (not including LULUCF) rose 4.5 % from the previous year. A total of about 762 Mt CO2e were released in 2021, about 33 Mt CO2e more than in the previous year. The increase is primarily due to CO_2 emissions, which are up by 5.5 %. The reason is that more lignite and hard coal was burned to generate electricity and, for weather-related reasons, more natural gas was used for heating. However, further expansion of renewables made it possible to limit the increase in emissions. The

[64] German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie 2021): Die Energie der Zukunft. Achter Monitoring-Bericht zur Energiewende (Eighth monitoring report on the energy system transformation); available at: https://www.bmwk.de/Redaktion/DE/Publikationen/Energie/achter-monitoring-bericht-energie-der-zukunft.pdf?__blob=publicationFile&v=32 [last checked on 14 Oct. 2022]

[65] German Environment Agency (Umweltbundesamt 2022) – Themenseite Treibhausgas-Emissionen: URL: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen

decline in nuclear energy was offset by renewable energy sources. Further efforts will be needed to pave the way for the transition to a climate-friendly energy supply.

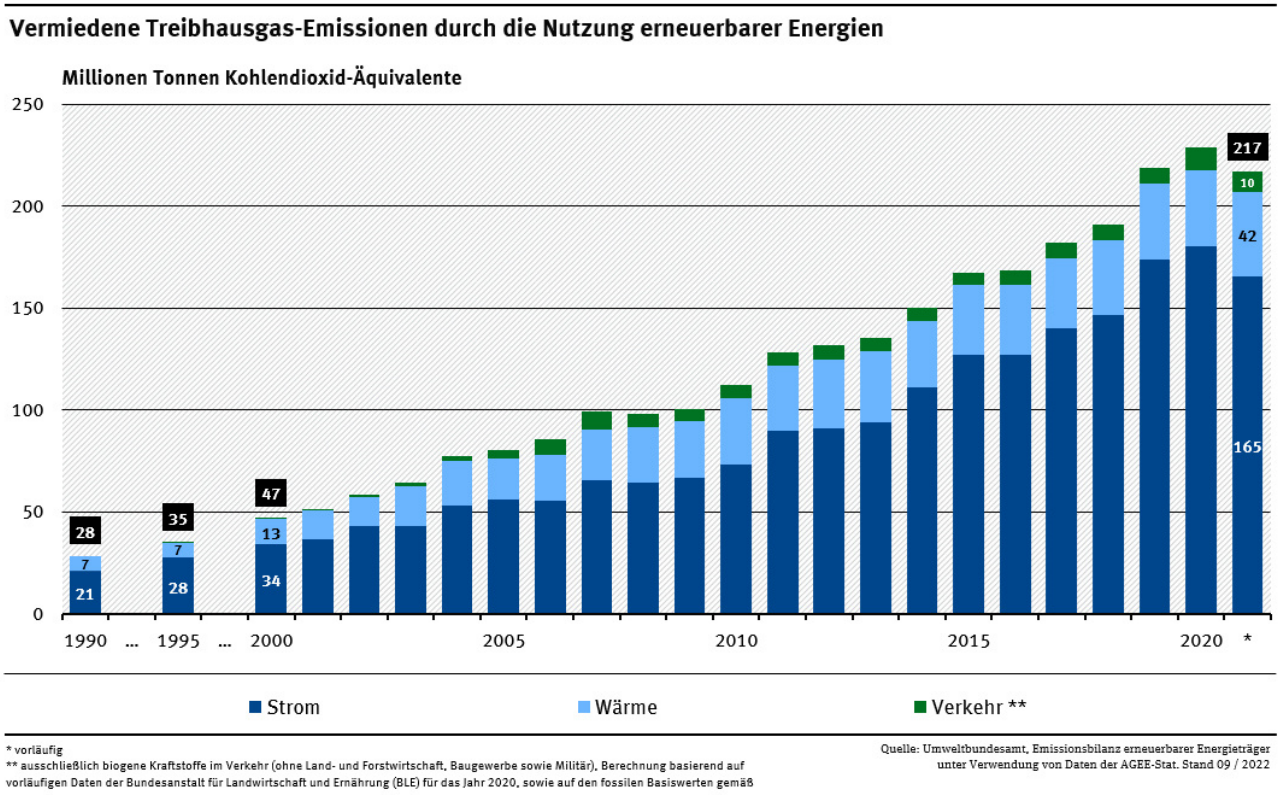


Figure 13: GHG emissions avoided through use of renewable energies[66]

2.6.5 Transformation of the energy system

In its Climate Change Act, Germany has obligated itself to achieve greenhouse-gas neutrality by the year 2045. To reach that goal, it will need to continue restructuring its energy system in a fundamental way. The success of the country's energy system transformation will depend centrally on significant improvements in energy efficiency and on accelerated expansion of renewable energies: Electricity generation, and climate-friendly, environmentally friendly restructuring of the electricity-generation sector, will play a central role in efforts to combat climate change. This is all the more so in that decarbonisation of the transport, heat-supply and industry sectors will call for large quantities of GHG-neutral electricity. And in areas in which electrification is either unfeasible or impractical, hydrogen will play an important role in the future energy system. In the following sections, and in Chapter 4.1, the trends outlined here are described in greater detail.

[66] translation: title = Greenhouse gas emissions avoided through the use of renewable energies; y-axis = Million tonnes of carbon dioxide equivalents; categories = Electricity, heat, transport (excluding biogenic transport fuels, agriculture, forestry, construction and military)

2.7 Transport

2.7.1 Transport services

The development of transports between 1991 and 2019 was shaped by a medium-level increase in passenger transports (measured in billions of passenger-km, Table 1) and by strong growth in goods transports (measured in tonne-km, Table 2). In 2020, passenger transports decreased considerably, as a result of the Covid-19 pandemic and the contact and travel restrictions it entailed. Goods transports were also affected – although less strongly – as a result of supply-chain disruptions.

Passenger transports increased by about 34 % between 1991 and 2019. In 2020, they decreased by more than 19 %. Individual motorised transport increased by 29 % between 1991 and 2019, and retained its dominant position. Its share in total passenger transport fell only slightly, from about 82 % in 1991 to about 78 % in 2019. Air transports grew faster than any other type of passenger transports. From 1991 to 2019, passenger transport by air, in German airspace, increased by about 218 %. As a result, its share in all passenger transports rose from 2.6 % to more than 6 %. In 2020, air transports decreased more sharply than any other type of passenger transports – by a total of about 74 %.

Passenger transports – Table 1:

	Individual motorised transport	%	Rail transport	%	Local public transport	%	Air transports	%	TOTAL
1991	713.5	81.6%	57.0	6.5%	81.6	9.3%	22.6	2.6%	874.7
1995	830.5	82.2%	71.0	7.0%	77.0	7.6%	32.5	3.2%	1011.0
2000	849.6	81.3%	75.4	7.2%	77.3	7.4%	42.7	4.1%	1045.1
2005	875.7	80.5%	76.8	7.1%	82.5	7.6%	52.6	4.8%	1087.6
2010	902.4	80.8%	83.9	7.5%	78.1	7.0%	52.8	4.7%	1117.2
2015	945.7	80.1%	91.7	7.8%	81.8	6.9%	61.5	5.2%	1180.8
2019	917.4	78.4%	102.0	8.7%	78.9	6.7%	71.8	6.1%	1170.2
2020	822.5	87.2%	57.5	6.1%	44.2	4.7%	18.7	2.0%	942.8
2030	991.8	78.6%	100.1	7.9%	82.8	6.6%	87.0	6.9%	1261.7

Table 1: Motorized passenger transport in Germany, measured in billions of passenger-kilometres (1991–2020, forecast for 2030); as of 2017, recalculation of the passenger-transport model: The data are not comparable with those of previous years. Source: Bundesministerium für Digitales und Verkehr (Federal Ministry for Digital and Transport) (2014/2021)[67]

Goods transports increased continuously from 1991 to 2008, to over 654.3 billion tonne-km. They decreased by more than 10 % in 2009 due to economic trends. In 2019, goods transports reached their highest level to date, 698 billion tonne-km. That figure represents growth of nearly 75 % between 1991 and 2019. In 2020, goods transports were much less strongly affected by the Covid-19 pandemic than passenger transports were – they decreased by about 4 %.

Goods transports by road increased by about 103 % between 1991 and 2019. The share of goods transported by road increased as a result from 61 % in 1991 to 71 % in 2019. This resulted in part from an increase in transit traffic – on which Germany has no influence under international treaties – due to the eastward expansion of the EU.

[67] German Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr 2021): Verkehr in Zahlen 2021/2022, unter https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-2021-2022-pdf.pdf?__blob=publicationFile last checked on 10 October 2022, and Federal Ministry for Digital and Transport (2014): Verflechtungsprognose 2030, available at: http://daten.clearingstelle-verkehr.de/276/1/verkehrsverflechtung-sprognose-2030-schlussbericht-los-3.pdf last checked on 10 October 2022)

The share for rail transport and inland waterway transport, which are both more energy-efficient, fell in the 1991–2019 period from about 35 % to about 26 %.

Table 2 provides details on the year-2020 trends for the various modes of transport involved.

Goods transports – Table 2:

Year	Road	%	Rail	%	Inland waterway	%	Pipelines	%	Air transports	%	TOTAL
1991	245.7	61.4%	82.2	20.6%	56.0	14.0%	15.7	3.9%	0.4	0.1%	400.0
1995	279.7	64.9%	70.5	16.3%	64.0	14.8%	16.6	3.8%	0.5	0.1%	431.3
2000	346.3	67.7%	82.7	16.2%	66.5	13.0%	15.0	2.9%	0.8	0.2%	511.3
2005	402.7	69.4%	95.4	16.4%	64.1	11.1%	16.7	2.9%	1.0	0.2%	580.0
2010	440.6	70.2%	107.3	17.1%	62.3	9.9%	16.3	2.6%	1.4	0.2%	627.9
2015	464.6	70.4%	121.0	18.3%	55.3	8.4%	17.7	2.7%	1.5	0.2%	660.1
2019	498.6	71.4%	129.2	18.5%	50.9	7.3%	17.6	2.5%	1.6	0.2%	698.0
2020	487.4	72.4%	120.9	18.0%	46.3	6.9%	16.7	2.5%	1.5	0.2%	672.8
2030	607.4	72.5%	153.7	18.4%	76.5	9.1%	-	-	-	-	837.6

Table 2: Goods transports in Germany, measured in billions of tonne-kilometres (1991-2020, forecast for 2030); for the period as of 2005, special-purpose vehicles (such as RVs, ambulances) are assigned to the automobile category (2005: about 400,000 vehicles). For the period as of 2008, not including temporarily deregistered vehicles. Source: Bundesministerium für Digitales und Verkehr (Federal Ministry for Digital and Transport) (2014/2021) [68]

For the period 2010 through 2030, the transport-integration forecast of the Federal Ministry for Digital and Transport forecasts moderate growth in passenger transports and relatively strong growth in goods transports. And roads will remain the predominant transport pathways.

2.7.2 Fleet of motor vehicles

As of 1 January 2022, a total of 59.6 million vehicles were registered in the centralized registry of the Federal Motor Transport Authority (KBA), including 48.5 million passenger cars, 4.8 million motorcycles, and 3.8 million trucks and semi-trailer tractors.[69]

Following a change to the KBA vehicle registry in 2008, temporarily deregistered vehicles are no longer included in the reported fleet. This means that data after 2008 are no longer comparable with data for the previous period and must be analysed separately.

It is clear nonetheless that the fleet of motor vehicles in Germany has increased constantly (Table 3): From 1991 to 2007, it increased by about 28 %. In the period 2008–2022, it increased by about 21 %, based on the new definition.

The number of passenger cars increased by about 18 % from 2008 to 2022. In 2022, about 31 % of passenger cars had a diesel engine, while only 12 % did in 1991. Electric cars account for 2.5 % of the fleet (618,000 battery electric vehicles (BEV), 566,000 plug-in hybrids). Off-road vehicles and SUVs account for about 16 % of passenger vehicles (7.7

[68] German Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr 2021): Verkehr in Zahlen 2021/2022, unter https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-2021-2022-pdf.pdf?__blob=publicationFile last checked on 10 October 2022, and Federal Ministry for Digital and Transport (2014): Verflechtungsprognose 2030, available at: http://daten.clearingstelle-verkehr.de/276/1/verkehrsverflechtung-sprognose-2030-schlussbericht-los-3.pdf last checked on 10 October 2022)

[69] German Federal Motor Transport Authority (Kraftfahrt-Bundesamt 2022): Zentralen Fahrzeugregister: https://www.kba.de/DE/Themen/ZentraleRegister/ZFZR/zfzr_node.html

million). Their share has grown disproportionately over the past 10 years (2012: 4.8 %, or 2.1 million).

The truck fleet grew considerably faster that the automobile fleet did: In the period 1991–2007, it grew by 55.6 %, and in the period 2008-2022, it grew by 52 %. Due to their powerful engines and the long distances they travel, trucks are responsible for a disproportionate amount of the emissions caused by motor vehicles. The fleet of two-wheeled motorcycles also increased considerably (1991–2007: 90 %; 2008–2022: 33 %).

Vehicle fleet – Table 3

Year	Automobiles and station wagons	Motorised two-wheelers	Trucks and semi-trailer tractors	Other motor vehicles	Total
1991	36.8	2.1	1.8	2.6	44.9
1995	40.4	2.3	2.3	2.5	49.2
2000	42.8	3.3	2.7	2.5	53.1
2005	45.4	3.8	2.8	2.6	54.5
2007	46.6	4.0	2.8	2.2	55.5
2008	41.2	3.6	2.5	2.1	49.3
2010	41.7	3.8	2.6	2.1	50.2
2015	44.4	4.1	2.9	2.3	53.7
2020	47.7	4.5	3.5	2.4	58.2
2022	48.5	4.8	3.8	2.5	59.6

Table 3: Motor-vehicle fleet, in 1,000s; Source: Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr) (2014/2021) [70] and Federal Motor Transport Authority (Kraftfahrt-Bundesamt) (2022) [71]

2.7.3 Fuel sales

Sales of fuel (all liquid and gaseous fossil fuels and biofuel) for the entire transport sector (not including maritime shipping) increased 12 percent during the 1991–2019 period (1991: 2,428 PJ, 2019: 2,722 PJ)[72]. In the following year, a decrease of 16 % occurred (2,292 PJ). In the present section, data for the year 2020 are listed separately, as a result of the often considerable pandemic-related (Covid-19) reductions in transport demand that occurred in that year.

Absolute fuel consumption in the road-transport sector increased between 1991 and 2019, from 2,117 PJ to 2,224 PJ (+5 %). In 2020, it decreased by 8.6 %, to 2,033 PJ. Decreases in the specific fuel consumption of motor vehicles have been partially offset by growing transport volumes – particularly in road transports of goods – and by a trend toward larger and more powerful vehicles.

The different fuels involved differ considerably in their contributions to sales trends. While sales of diesel fuel increased by 67 % in the 1991-2019 period (decrease in 2020 in comparison to the previous year: -11 %), sales of petrol decreased sharply, by 46 % (2020: -10 %). Biofuels accounted for about 7.5 % of the energy used in road transports in Germany in 2020. In contrast to the trend for fuels used for road, rail and inland waterway

[70] German Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr 2021): Verkehr in Zahlen 2021/2022, unter https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-2021-2022-pdf.pdf?__blob=publicationFile last checked on 10 October 2022, and Federal Ministry for Digital and Transport (2014): Verflechtungsprognose 2030, available at: http://daten.clearingstelle-verkehr.de/276/1/verkehrsverflechtungs-prognose-2030-schlussbericht-los-3.pdf last checked on 10 October 2022)

[71] German Federal Motor Transport Authority (Kraftfahrt-Bundesamt 2022): Zentralen Fahrzeugregister: https://www.kba.de/DE/Themen/ZentraleRegister/ZFZR/zfzr_node.html

[72] German Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr 2021): Verkehr in Zahlen 2021/2022, available at https://www.bmvi.de/SharedDocs/DE/Publikationen/G/verkehr-in-zahlen-2021-2022-pdf.pdf?__blob=publicationFile last checked on 10 October 2022

transport, sales of aviation fuel (kerosene) increased markedly – by 126 % – in the 1991–2019 period. In the following year, the demand for kerosene decreased sharply, and sales of that fuel decreased by 54 %.

2.7.4 Impacts on GHG emissions

For the most part, GHG-emissions trends in the transport sector (Table 4) are shaped by tends in road transports. In the classification used by the UN Framework Convention on Climate Change, emissions by road traffic are responsible for about 98 % of GHG emissions in transport, because air transports include only domestic aviation and shipping includes only trips between two ports that both belong to the reporting country. The international components of air transports and shipping are recorded for purposes of information only. Furthermore, emissions from generation of the electric power used in the transport sector are assigned to electricity generation, where they originate.

In 2020, the Covid-19 pandemic had the effect of considerably reducing emissions in the transport sector. This occurred primarily via reductions in transport mileage, along with the associated lower fuel consumption. Consequently, the emissions trends described in the following are less the result of successful reduction measures and more one of an exceptional, pandemic-caused situations.

Road-transports' GHG emissions decreased by 10 % between 1991 and 2020. Following a downturn between 1991 and 1998, they grew continuously beginning in 1999. In 2009, they were even slightly higher than the levels reported for 1991. Because road-transport emissions account for such a large percentage share of transport emissions overall, this trend is reflected in the GHG emissions for the entire transport sector.

In the period between 1991 and 2019, emissions in domestic aviation decreased by less than 1 %. As the result of a drop in demand tied to the Covid-19 pandemic, emissions decreased by 53 % from 2019 to 2020.

The conversion of the railways from diesel to electric traction, and technical and operational improvements in efficiency, led to significant emissions reductions. With respect to the year 1991, annual GHG emissions through 2020 decreased by 72 %.

In national (domestic) shipping, annual emissions in 1991–2020 period also decreased markedly – by 52 %. This was due to such factors as efficiency improvements, increased refuelling in other countries and reductions in the volume of inland-water transports.

Overall in 2020, therefore, transport (not including international aviation and maritime shipping) was responsible for 146.4 Mt CO2e – or nearly 12 % less than in the base year 1991. The decrease through 2019 amounted to only 1.4 %. In 2020, transport accounted for a 20 % share of Germany's total GHG emissions. In 2019, the corresponding share, at about 21%, was only slightly higher.

Year	Road transports	National aviation	Railway transport	National shipping	Total	International aviation
1991	158,351	2,267	2,817	2,905	**166,341**	11,933
1995	169,100	2,157	2,476	2,441	**176,175**	15,194
2000	174,706	2,663	1,954	1,628	**180,951**	19,405
2005	154,351	2,501	1,375	1,601	**159,829**	22,982
2010	148,108	2,334	1,121	1,405	**152,967**	24,466
2015	157,023	1,999	1,025	1,673	**161,719**	24,792
2019	159,404	2,254	834	1,582	**164,074**	29,908
2020	143,134	1,050	785	1,405	**146,374**	13,754

Table 4: Development of GHG emissions in the transport sector, in 1,000s of t CO_2-eq. (1991-2020); international aviation is reported for informational reasons. Source: German Environment Agency (2022) [73]

At the time this report was being prepared, only provisional emissions data were available for the year 2021. Nonetheless, it was clear that transport emissions, at about 148.1 Mt CO2e, were higher than they had been in 2020. They decreased by about 11 % in 2021, with respect to the base year 1991. Pursuant to the provisional data for 2021, national aviation accounted for about 0.76 Mt CO2e, railway transports accounted for about 0.79 Mt CO2e and national shipping accounted for about 1.4 Mt CO2e. Road transports contributed about 145.1 Mt CO2e in 2021. As in previous years, they accounted for the largest share of transport emissions. Because the data for 2021 are provisional, these results may change slightly.

2.8 Industry

2.8.1 Structure

In Germany, industry – to a far greater extent than in comparable countries – is a key basis for growth, prosperity and jobs. In 2021, it accounted for about 755 billion euro of gross value added and some 10 million employees.[74]

Industry is the central basis of Germany's export strength. Germany is a global leader in many industrial sectors, such as the automotive industry, machinery and plant engineering and the chemical and pharmaceutical industries.

Germany's industrial structure is dominated by manufacturing of machinery and vehicles, which accounts for 42 % of its gross value added and 32 % of its employment (cf. Figure 14). The country's second-largest sector is food, beverages and tobacco; it accounts for 8 % of gross value added and 11 % of employment. Other important sectors include basic chemicals, accounting for 4 % of gross value added, along with the a) paper industry and b) processing of non-metallic minerals, with each contributing 2 % of gross value added. Numerous other industrial sectors each contribute 1 % or less to gross value added.

In the face of global challenges such as climate change, scarcity of resources, digitalisation of the economy and society, and demographic change, German industry has to be able to change and adapt. At the same time, such challenges hold great opportunities for German industry. This is because many of the impacts and secondary effects of such challenges can only be addressed in cooperation with industry. With its capacities, resources and ability to innovate, industry can play a key role in successful efforts to address the great challenges of our time.

[73] German Environment Agency (Umweltbundesamt 2022): Themenseite Treibhausgas-Emissionen: URL: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen

[74] German Federal Statistical Office - Gross value added price adjusted (Statistisches Bundesamt - GENESIS-Online - Bruttowertschöpfung preisbereinigt 2022), URL: https://www-genesis.destatis.de/genesis/online

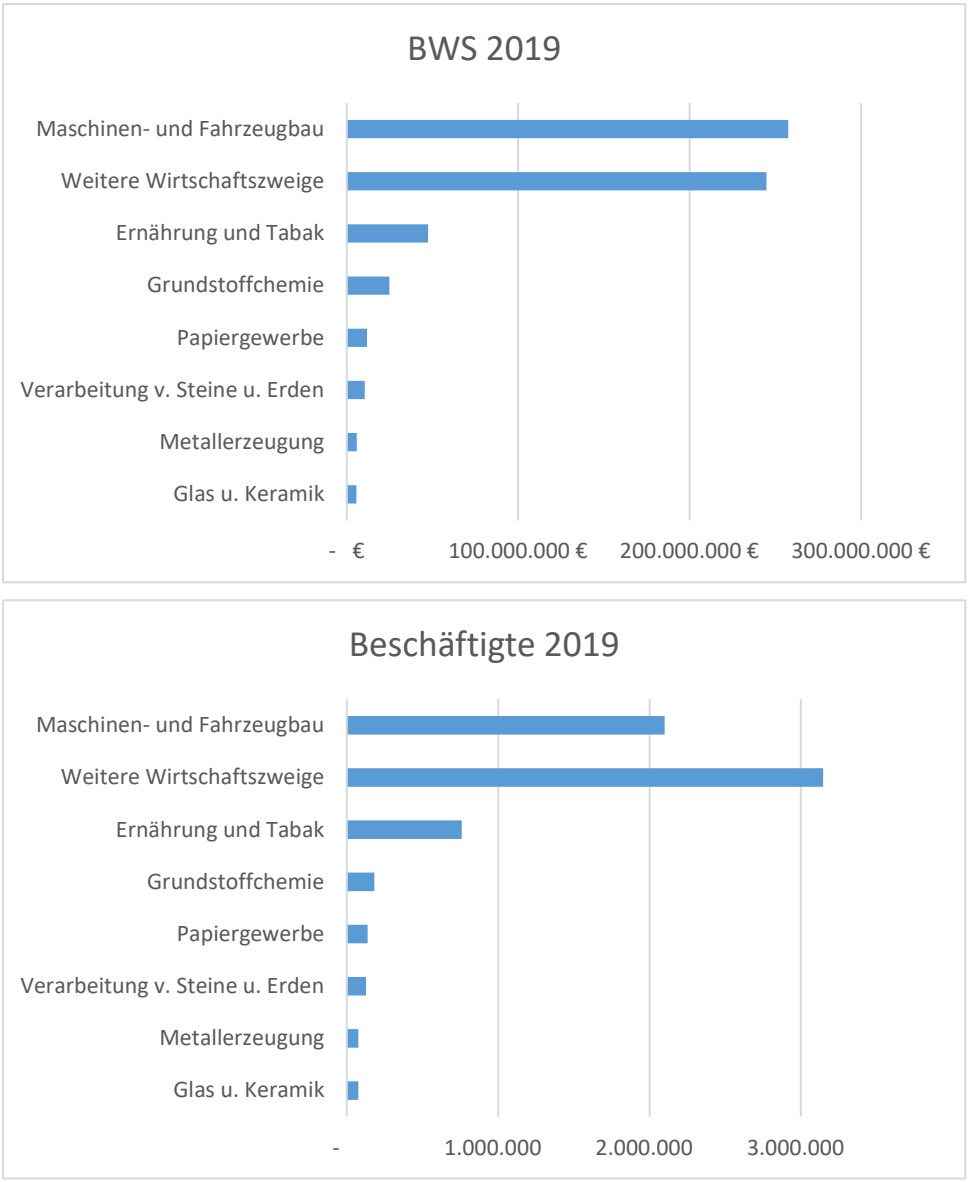


Figure 14: Gross value added and employment in the industry sector in 2019. Source: Destatis[75]

2.8.2 Impacts on GHG emissions

In 2021, the industry sector was responsible for about 24 percent of total GHG emissions.[76] The iron and steel industry, cement industry and chemical industry are the three leading industry emitters of GHG emissions (cf. Figure 15). In recent decades, industry has continuously improved the GHG efficiency of its value creation. Between 2010 and 2019, its GHG emissions decreased by about 3 percent – during a phase of economic growth with rising gross value added. To meet its goal under the Climate Change Act, industry needs to significantly increase its rate of emissions reduction, and to reach a reduction level of about 35 percent between 2021 and 2030. It now needs to make larger jumps in its reduction progress – for example, by replacing fossil fuels with renewable energy sources and by making

[75] German Federal Statistical Office - Gross value added price adjusted (Statistisches Bundesamt - GENESIS-Online - Bruttowertschöpfung preisbereinigt 2022), URL: https://www-genesis.destatis.de/genesis/online
[76] German Environment Agency (Umweltbundesamt 2022): Trendtabellen THG (03/2022)

an industry-wide transition from conventional production processes to innovative, climate-neutral processes.

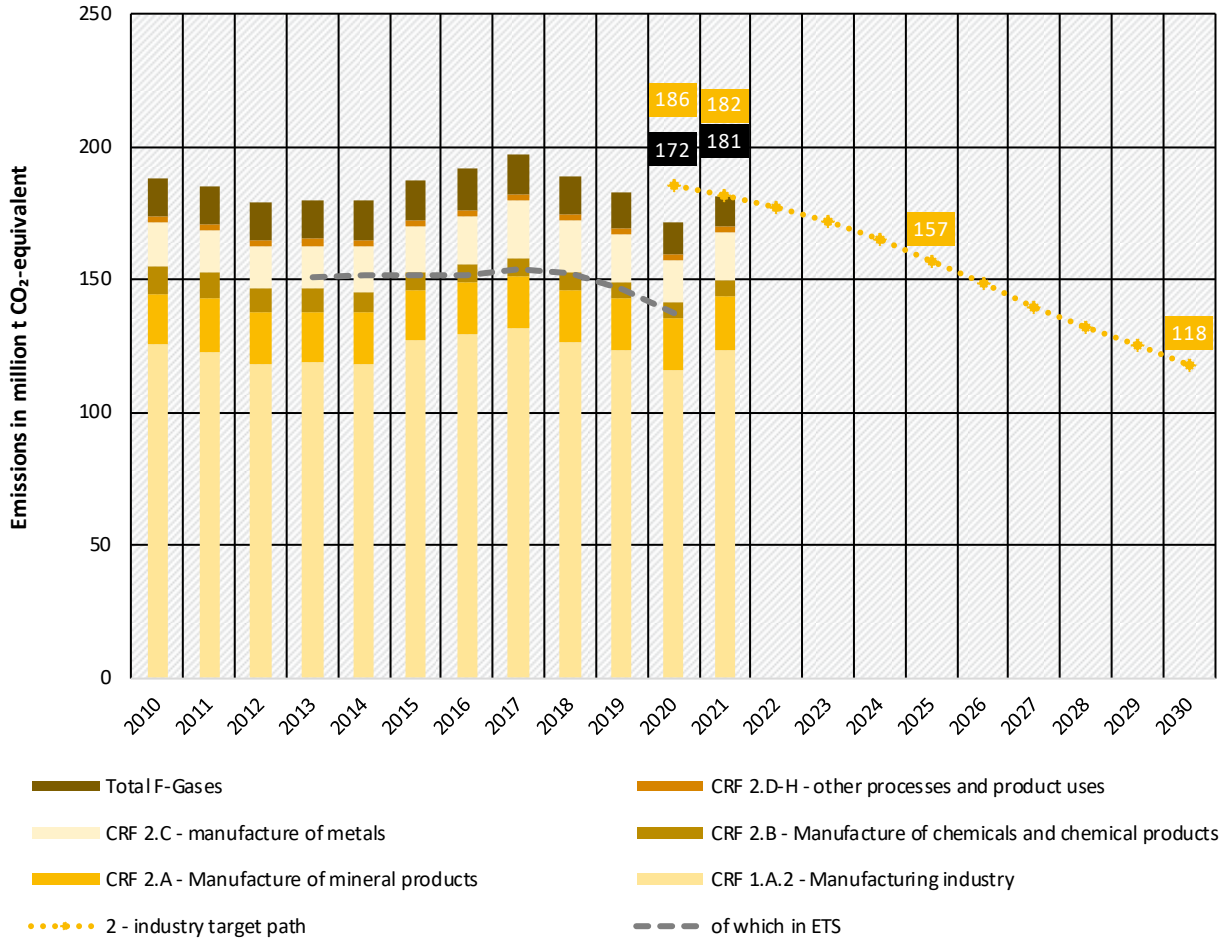


Figure 15: GHG emissions and industry-sector goals under the Federal Climate Change Act (KSG), by industry sector Source: German Environment Agency (2022) [77]

2.9 Waste management and wastewater treatment

2.9.1 Waste quantities

A total of 51.0 million t (tonnes) of municipal waste were produced in Germany in 2020[78]. The recycling/recovery rate for all municipal waste amounted to 98 % in 2020, or an increase of 27 percentage points over the corresponding figure in 2006. The recycling rate in 2020 was 67 %.

Along with municipal waste, the following quantities of other waste types were produced in 2020: 28.6 million t of waste from extraction and processing of mineral resources, 229.3 million t of construction and demolition waste, 47.3 million t of other waste (in particular,

[77] German Environment Agency (Umweltbundesamt 2022): Themenseite Treibhausgas-Emissionen: URL: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen or press release 15/2021: https://www.umweltbundesamt.de/presse/pressemitteilungen/treibhausgasemissionen-stiegen-2021-um-45-prozent

[78] German Federal Statistical Office (Statistisches Bundesamt 2022)

waste from production and industry), and 57.7 million t of waste from wastewater treatment plants.

Germany produced a total of 414.0 million t of waste in 2020 (after deduction of waste from waste treatment plants, to prevent double-counting; this yields the net waste production: 356.3 million t). The recovery rate for net waste production is 81 %, while the recycling rate is 73 %. Of this waste, only about 17 % is sent to landfills.

2.9.2 Legal basis, and objectives of waste management

The fundamental legislation governing waste management is the Closed Cycle Management Act (Kreislaufwirtschaftsgesetz – KrWG) of 24 February 2012[79]. 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 on taking back individual product groups or materials have been adopted with the objective of preventing and recovering certain waste fractions. Under requirements of laws governing use of landfills, storage of non-pretreated municipal waste was completely terminated as of 1 June 2005, with the aim of preventing further emissions (landfill gas, polluted leachate) from landfills. As a result, since 1 June 2005, biodegradable waste and waste with a high calorific value may no longer be placed in landfills; such waste types must now be treated in composting plants, digestion plants, waste incineration plants or mechanical-biological treatment (MBT) plants.

2.9.3 Recovery and treatment of biowaste and green waste

With its systems for separate collection and treatment of biowaste and green waste, Germany has achieved a high standard, internationally, in recovery and treatment of biodegradable waste.

2.9.4 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 June 2005. Only about 101 of the many household waste landfills that the country used to have in operation were still operational in 2020.[80] According to the Landfill Ordinance (Deponieverordnung), only waste containing less than 3 percent by weight total organic carbon (TOC) or that does not contribute to gas formation may be stored in those landfills.

The remaining old household-waste landfills have been shut down or remediated in compliance with statutory requirements. For the larger centralized 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 layer.

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

[79] German Federal Law Gazette (Bundesgesetzblatt I, 2012: p. 212.)

[80] German Federal Statistical Office (Statistisches Bundesamt - GENESIS-Online, 2022): Abfallentsorgung: Deutschland, Jahre, Anlagenart, Abfallarten: Filter nach Anlagen die Siedlungsabfälle (EAV-20) verarbeiten (waste management: Germany, years, plant type, waste type: filter by plants that process municipal waste). URL: https://www-genesis.destatis.de/genesis/online[...] , last checked on 16 Dec. 2022)

continue to decrease from their current low level and then disappear over the next few decades. The federal government has issued requirements calling for aeration – and, thus, more-rapid degassing – of landfill layers in which older waste is stored.

2.9.5 Impacts on GHG emissions

According to calculations of the German Environment Agency, methane emissions from landfills fell by about 80 %, from 1.36 million t in 1990 to 0.27. million t in 2020. This is equivalent to a total reduction of 27.5 million tonnes of CO_2 equivalents through 2020. In the assessment of the German Environment Agency, the key reason for this reduction is that landfilling of biodegradable waste has been prohibited since 2005, with the result that landfilling of waste with significant methane formation no longer occurs. For conformance with pertinent requirements, settlement waste and other biodegradable waste must be pretreated via thermal or mechanical-biological processes. Consequently, composting/digestion of household and commercial biowaste, and mechanical-biological treatment of residual waste, have been considerably expanded. Biological treatment also contributes to the formation of GHG emissions, albeit to a small extent. In 2020, composting and digestion plants emitted about 28.6 kt CH_4 and 1kt N_2O. The emissions produced by MBTs are negligible, therefore – they amount to a total of about 1 Mt CO2e.

2.9.6 Municipal wastewater treatment

2.9.6.1 Wastewater production

In Germany, 95.7 % of the population is connected to public wastewater treatment plants. About 75 % percent of wastewater from the rest of the population is discharged into small treatment plants, and about 18 % is discharged into septic tanks. [81] The country's some 8,900 municipal sewage treatment plants handle about 9 billion m^3 of municipal wastewater from homes and businesses. Half of the wastewater is used water and half is precipitation and infiltration water. The volume of precipitation and infiltration water involved, as a share of total wastewater, has decreased continuously since 2010, from 50 % to 43 %. In terms of population equivalents (PE), and on a yearly average, the wastewater has a load of approximately 115 population equivalents. One PE is equivalent to a daily chemical oxygen demand (COD) of 120 g. Some 0.9 billion m^3 of wastewater are treated in industrial wastewater treatment plants.

Public wastewater treatment plants produce about 1.7 million t of sewage sludge per year. Of that quantity, about 1.3 million t are thermally treated, while 0.3 million t are used in agriculture.[82]

[81] German Federal Statistical Office (Statistisches Bundesamt 2021) – Gemeinden mit öffentlicher und privater Abwasserentsorgung – Öffentliche Abwasserentsorgung nach Ländern 2019 (municipalities with public and private wastewater treatment – public wastewater management by Länder, 2019). URL: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Wasserwirtschaft/Tabellen/ww-02-abwasserentsorgung-2019.html (last checked on 16 Dec. 2022)

[82] German Federal Statistical Office (Statistisches Bundesamt 2021) – Presse: Drei Viertel des kommunalen Klärschlamms wurden 2019 verbrannt, ein Viertel stofflich verwertet (three quarters of municipal sewage sludge was incinerated in 2019, while one quarter was used materially. URL: https://www.destatis.de/DE/Presse/Pressemitteilungen/2021/01/PD21_036_32214.html (last reviewed on 16 Dec. 2022)

2.9.6.2 GHG emissions from municipal wastewater treatment plants and small private wastewater treatment plants

Municipal wastewater treatment in Germany normally takes place under aerobic conditions (municipal wastewater treatment plants and small private treatment systems), i. e., methane emissions from municipal wastewater treatment are very low. Open digestion for sludge stabilisation, which did cause methane emissions, was terminated in 1994. Sludge stabilisation using anaerobic digestion can be economical for municipal wastewater treatment plants above 50,000 PE; in such cases, 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 about 400,000 people were still discharging wastewater into septic tanks in 2019.[83] However, the organic load discharged into septic tanks has been drastically reduced since 1990, resulting in a strong downward trend for methane emissions (reduction from about 18.7 kt/a in 1990 to about 0.79 kt/a in 2020[84]).

Nitrous oxide emissions can occur as a by-product of municipal wastewater treatment, especially in connection with denitrification, in which gaseous end products – mainly, molecular nitrogen – are formed from nitrate. The level of nitrous oxide emissions (N_2O) in the wastewater sector depends on per-capita intakes of protein, so it is directly related to lifestyles and consumption patterns.

According to calculations done for the 2022 National Inventory Report (NIR)[85] 17.4 kt of methane (435.5 kt CO_2-eq.) and 1.45 kt of nitrous oxide (431.6 kt CO_2-eq.), or a total of about 0.87 million t CO_2-eq., were produced by municipal wastewater treatment plants in 2020. Methane emissions from wastewater treatment have declined by more than 80 % since 1990, while nitrous oxide emissions have decreased by about 65 %.

2.10 Buildings sector – heating and cooling

2.10.1 Building-related energy consumption in 2020

The energy-related application areas tied directly to use of buildings include space heating, production of hot water, cooling (air conditioning) and space illumination, in the consumption sectors industry, and trade, commerce and services. The building-related final energy consumption in these areas in 2020 amounted to 835 TWh. This quantity of final energy consumption in the building sector was 125 TWh, or 13 %, lower than the corresponding figure for 2008.

[83] German Federal Statistical Office (Statistisches Bundesamt 2021) – Gemeinden mit öffentlicher und privater Abwasserentsorgung – Öffentliche Abwasserentsorgung nach Ländern 2019 (municipalities with public and private wastewater treatment – public wastewater management by Länder, 2019). URL: https://www.destatis.de/DE/Themen/Gesellschaft-Umwelt/Umwelt/Wasserwirtschaft/Tabellen/ww-02-abwasserentsorgung-2019.html (last checked on 16 Dec. 2022)

[84] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022, verfügbar unter (2022 National Inventory Report, available at): https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

[85] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022, verfügbar unter (German Environment Agency (2022): 2022 National Inventory Report, available at): https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

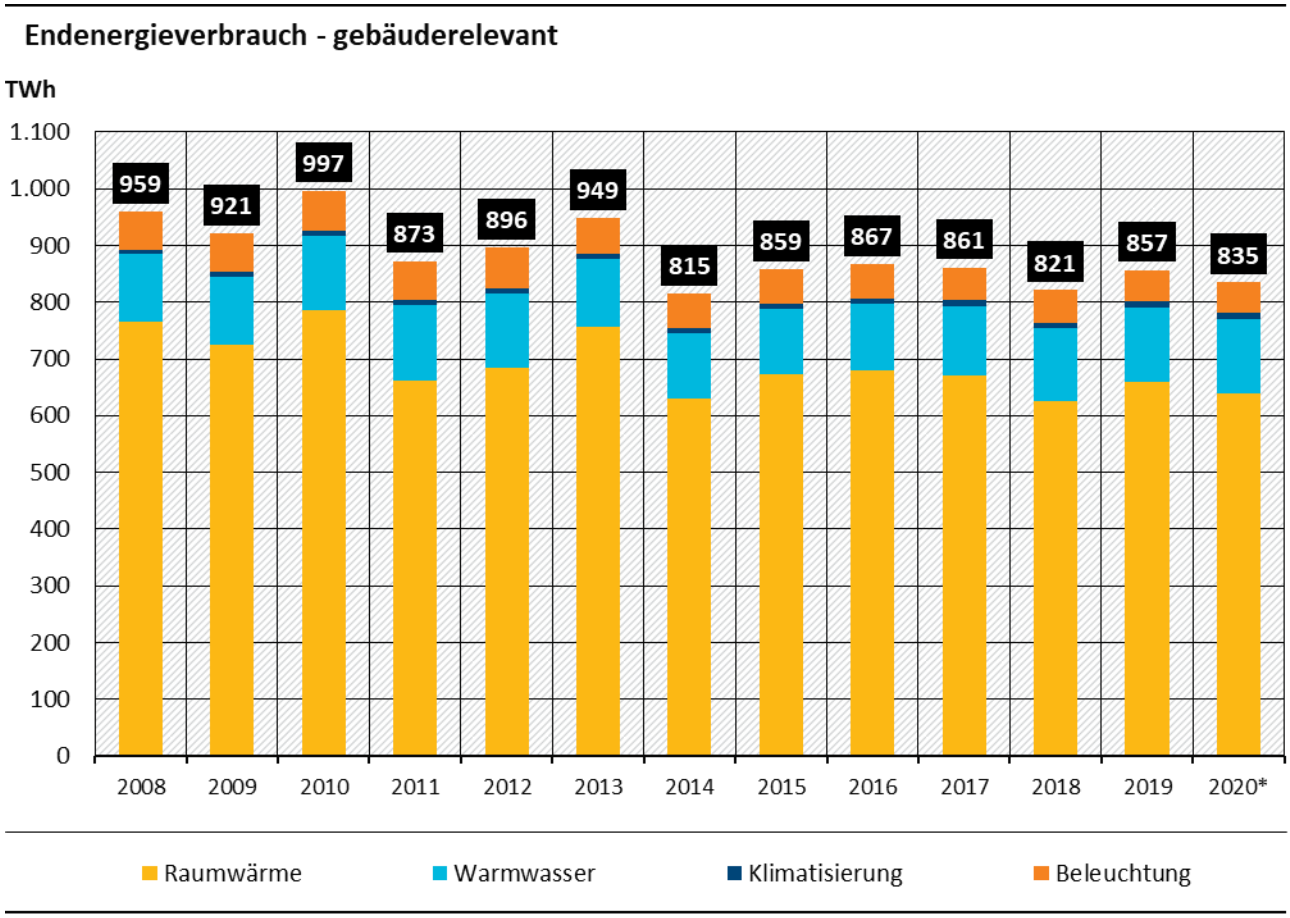


Figure 16: Building-related final energy consumption[86]

As Figure 16 shows, space heating accounted for the largest share – 76.5 % – of the final energy consumed in the buildings sector in 2020. Because final energy consumption for space heating depends strongly on weather conditions, it varies widely over time. The share of building-related final energy consumption used for water heating amounted to 15.8 % in 2020. Final energy consumption for lighting accounted for a 6.5 % share. Air conditioning in buildings accounted for 1.2 % of final energy consumption in 2020. Also, final energy consumption for air conditioning in buildings increased by more than 31.9 % between 2008 and 2020.

In 2020, renewable energies provided 114 TWh of the energy used for space heating, and 16 TWh of that used for heating water. The corresponding share for renewable energies increased to 16 % in the process. In 2008, renewable energies' share of building-related final energy consumption was 7 %[87]

[86] translation: title = Final energy consumption - building-relevant; categories = room heating, Hot water, Air conditioning, Lighting; footnote = * preliminary data

[87] German Working Group on Energy Balances (Arbeitsgemeinschaft Energiebilanzen 2021)

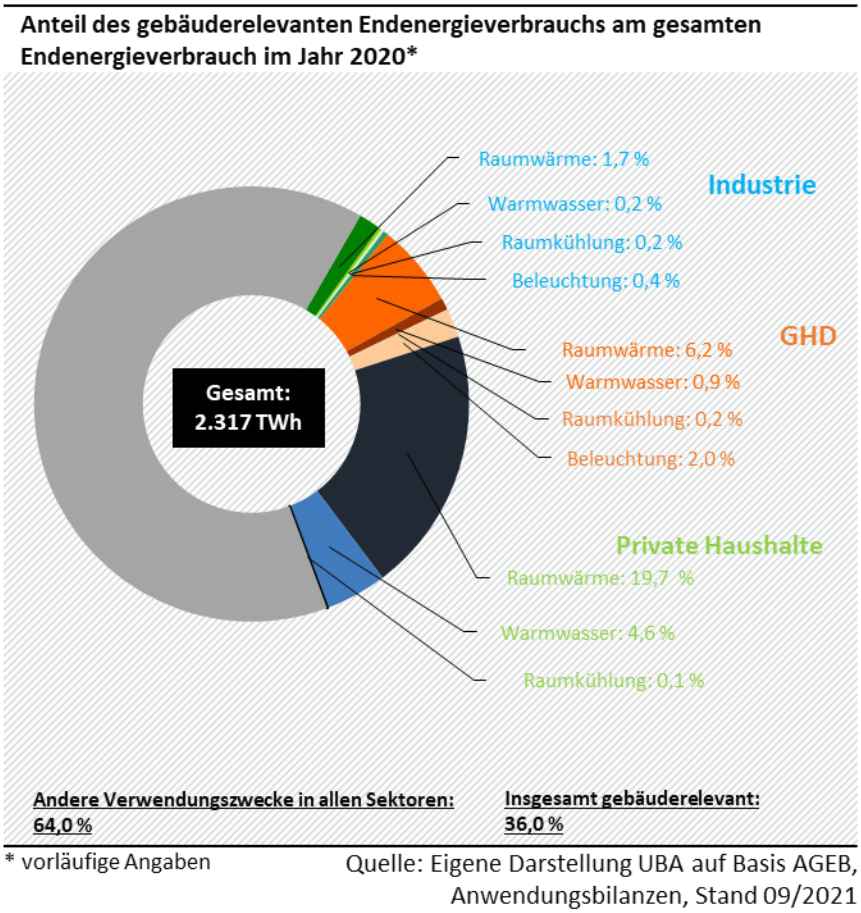


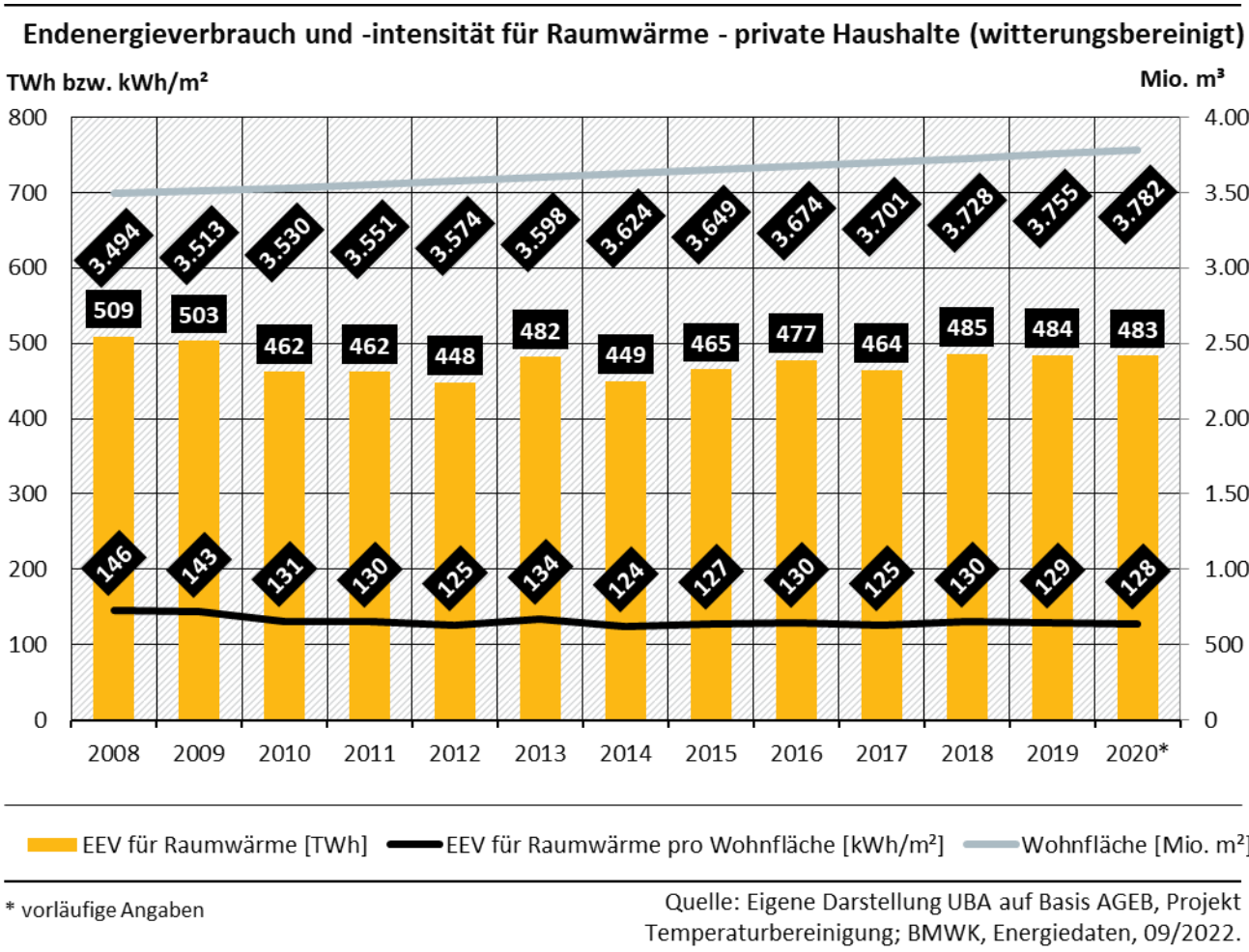
Figure 17: Building-related final energy consumption, by sectors[88]

As Figure 17 makes clear, space heating in private households accounts for an important share of both buildings-related final energy consumption and total final energy consumption. For this reason, efforts to reduce heating requirements in buildings are playing a central role in Germany's energy system transformation (Energiewende). While efforts to transform the heat sector, aimed at increasing reliance on renewable energies, play a key role in efforts to achieve the country's climate goals, efforts to reduce the sector's energy requirements are paramount, because a) they pave the way for efficient use of renewable energies, and b) the available renewable energies are not limitless. All in all, space heating requirements have decreased by 16.7 % since 2008. In the process, industry (-29.2 %) and the trade, commerce and services sector (-30.8 %) achieved greater reductions in energy consumption for space heating, from 2008 to 2020, than did private households (-10.2 %). Over the same period, and in all consumption sectors combined, final energy consumption for water heating increased by 11.1 %, and final energy consumption for heating, ventilation and air conditioning (HVAC) increased by 31.1 %.

[88] translation: title = Share of building-relevant final energy consumption in total final energy consumption in 2020; high level categories = industry, commercial/institutional; private households; lower level categories = room heating, hot water, room cooling, Lighting (not in private households); text = Other uses in all sectors 64.0%, Total building-relevant: 36.0%; footnote = preliminary data

2.10.2 Energy efficiency in buildings of private households

In light of space heating's large share of private households' share of total final energy consumption, efforts to improve energy efficiency in existing buildings are playing an important role in Germany's transition to a new energy era (Energiewende).



* vorläufige Angaben

Quelle: Eigene Darstellung UBA auf Basis AGEB, Projekt Temperaturbereinigung; BMWK, Energiedaten, 09/2022.

Figure 18: Final energy consumption and energy intensity for space heating – Private households sector[89]

Figure 18 shows how energy requirements for space heating have been reduced in Germany's residential buildings. These energy savings were achieved in spite of an increase of living space. As a result, the energy intensity for space heating was reduced from 146 to 128 kWh/m^2 between 2008 and 2020.

2.10.3 Building-related GHG emissions

Emissions in the buildings sector decreased from 119 Mt CO2e in 2020 to about 115 Mt CO2e in 2021 (a decrease of 3.3 percent). In spite of this emissions reduction, the buildings sector has exceeded its allotted annual emissions – pursuant to the Federal Climate Change Act, a quantity of 113 Mt CO2 – as it did in the previous year. In large measure, the

[89] translation: title = Final energy consumption (FEC) and intensity for space heating - private households (weather-adjusted); y-axis left = TWh resp. kWh/m2; y-axis right = mio. m3; categories = FEC for space heating [TWh], FEC for space heating per living space [kWh/m2], living space [million m2]; footnote = *preliminary data

emissions reduction is an anomalous effect resulting from considerably lower heating-oil purchases. As a result of reasonable prices, and in preparation for the Fuel Emissions Trading Act (BEHG), many of the country's heating-oil-storage facilities were topped up in 2019 and 2020.

Natural gas consumption increased, however, as a result of weather conditions. The year 2021 was relatively cool, with the number of degree days increasing by about 13 percent in comparison to the previous year. This led to higher heating requirements and increased emissions. According to an analysis of the German Environment Agency (UBA), this effect was offset by reductions of heating-oil purchases, to the extent that a net reduction of emissions resulted. In all likelihood, climate-protection measures also contributed to the emissions reduction that occurred in 2020.

2.11 Agriculture

2.11.1 Structure

In 2020, some 262,800 farms in Germany managed about 16.6 million ha of agricultural land.[90] In comparison to the corresponding figure for 2016, the number of farms decreased by about 4.6 %. An even more pronounced decrease occurred between 2010 and 2020 (about 12.1 %). The average farm size in 2020 was about 63 ha. About 62 % of the land used for agriculture is managed by farms that have at least 100 ha of agriculturally managed land. The mean size of farms tends to decrease from east to west and from north to south. About 60 % of the land was leased in 2020.[91] About 49 % of farms are run as a secondary occupation.[92] This partially explains why the some 937,900 people who work in agriculture are equivalent to only about 500,000 full-time equivalents.[93]

In 2020, 70 % of land used for agriculture was cultivated, while 29 % was managed as permanent grassland and 1 % was used for permanent crops.[94] The main crops grown on cultivated land included winter wheat (23.7 %), silo maize (19.7 %), winter barley (11.2 %) and winter oilseed rape (8.2 %). The area under cultivation with energy crops (primarily silo maize, for use as a fermentation substrate for biogas production) has decreased in recent

[90] German Federal Statistical Office (Statistisches Bundesamt 2021) Landwirtschaftliche Betriebe – Ausgewählte Merkmale im Zeitvergleich (Agricultural operations – selected characteristics in chronological comparison); URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Landwirtschaftliche-Betriebe/Tabellen/ausgewaehlte-merkmale-zv.html

[91] German Federal Statistical Office (Statistisches Bundesamt 2021) – Eigentums- und Pachverhältnisse (ownership and leases), Fachserie 3 Reihe 2.1.6, 2020. URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Landwirtschaftliche-Betriebe/Publikationen/Downloads-Landwirtschaftliche-Betriebe/eigentums-pachtverhaeltnisse-2030216209005.xlsx?__blob=publicationFile

[92] German Federal Statistical Office (Statistisches Bundesamt 2021) – Rechtsformen und Erwerbscharakter (legal forms and orientation to profit) – Fachserie 3 Reihe 2.1.5 – 2020. URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Landwirtschaftliche-Betriebe/Publikationen/Downloads-Landwirtschaftliche-Betriebe/rechtsformen-erwerbscharakter-2030215209005.xlsx?__blob=publicationFile

[93] German Federal Statistical Office (Statistisches Bundesamt 2021) – Arbeitskräfte und Berufsbildung der Betriebsleiter/Geschäftsführer (workforces, and vocational training of managers / managing directors) – Fachserie 3 Reihe 2.1.8 – 2020. URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Landwirtschaftliche-Betriebe/Publikationen/Downloads-Landwirtschaftliche-Betriebe/arbeitskraefte-2030218209005.xlsx?__blob=publicationFile

[94] German Federal Statistical Office (Statistisches Bundesamt - GENESIS-Online, 2021) URL: https://www-genesis.destatis.de/genesis/online

years[95]. The installed electrical capacity of all German biogas plants had grown to more than 5,860 MW as of 2020, however[96].

The structural change occurring in the German animal husbandry sector has continued in recent years. In 2020, and with respect to 2010, the country's cattle and swine herds decreased by 10% and 4.6%, respectively. Also, the number of farms with livestock has been decreasing as well. The number of such farms in 2020 was about 47,300 (22 %) lower than it was in 2010.[97]

Some 26,100 farms, or 10 % of all farms, were operated as organic farms in 2020. The share of organically farmed land, with respect to the total area of land used for agriculture, was nearly 10 % in 2020.[98]

The value of products produced in 2020 by the German agricultural sector was about 57.6 billion euro, with crop cultivation and animal husbandry each accounting for about half of that amount.[99] Also, about 18 % of the total production value was generated via milk production. In connection with crop cultivation, it must be noted that forage crops function as an intra-sectoral advance input, since they are a required input for animal husbandry.

2.11.2 Impacts on GHG emissions

The agricultural sector's contribution to Germany's GHG emissions (not including LULUCF emissions) was about 8% in 2020.[100]

Methane emissions accounted for the lion's share of the agriculture sector's GHG emissions – 57 % – in 2020. They occur in enteric fermentation (42.5 % of GHG emissions), in treatment of farm manure (11.5 % of GHG emissions) and in processes connected to storage of digestates of renewable resources (2.3 % of GHG emissions). Nitrous oxide emissions account for a 38.9 % share. They occur via spreading of farm manure and mineral fertiliser on agricultural soils (33.3 % share of GHG emissions), treatment of farm manure (5.2 % share of GHG emissions) and processes for storing of digestates (0.5% share of GHG emissions). A small share (4.7 %) consists of CO_2 emissions from liming, from use of urea as a mineral fertiliser, and from other carbon-based fertilisers.

Emissions from agriculturally related land-use changes, such as draining of peatlands or ploughing of grassland, are assigned not to agriculture but to Land Use, Land-use Changes and Forestry (LULUCF), in keeping with regulations for climate reporting. About 70 % of peatlands are used for agriculture. While such agriculturally used soils (organic soils) account for slightly less than 7 % of the utilised agricultural area (cropland and grassland), they emitted about 6 % of Germany's total GHG in 2020. For this reason, the federal

[95] Agency for Renewable Resources (Fachagentur Nachwachsende Rohstoffe 2022)
[96] Biogas Association (Fachverband Biogas 2021)
[97] German Federal Statistical Office (Statistisches Bundesamt - GENESIS-Online, 2022) https://www-genesis.destatis.de/genesis/online
[98] German Federal Statistical Office (Statistisches Bundesamt 2021) Betriebe mit ökologischem Landbau (farms with organic farming) – Fachserie 3 Reihe 2.2.1 – 2020. URL: https://www.destatis.de/DE/Themen/Branchen-Unternehmen/Landwirtschaft-Forstwirtschaft-Fischerei/Landwirtschaftliche-Betriebe/Publikationen/Downloads-Landwirtschaftliche-Betriebe/oekologischer-landbau-2030221209005.xlsx?__blob=publicationFile
[99] German Federal Agency for Agriculture and Food (Bundesanstalt für Landwirtschaft und Ernährung 2022): Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland 2021. Bonn: Bundesanstalt für Landwirtschaft und Ernährung (Federal Agency for Agriculture and Food) (BLE). URL: https://www.bmel-statistik.de/archiv/statistisches-jahrbuch/
[100] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

government has included the future restructuring of this sector in its Climate Action Plan 2050. For the area of land use, top priority has been given to protecting and improving forest land's function as an emissions sink. Other aims include prohibiting grassland tillage, and protecting peatlands, although note is taken of the need to take account of site-specific circumstances and of possible conflicts of objectives with regard to ownership rights or food production. Via a federal-Länder target agreement calling for protecting peatlands as a climate action measure (Zielvereinbarung zum Klimaschutz durch Moorbodenschutz), the competent federal and Länder ministries have agreed on a joint framework for ambitious protection of peatlands. The agreement calls for reducing annual GHG emissions from peatlands by five million tonnes of CO_2 equivalents by the year 2030. The federal government's National Peatland Protection Strategy (Nationale Moorschutzstrategie), which was adopted in November 2022, builds on that goal. The strategy serves as the political framework, at the federal level, for all aspects of peatland protection in Germany.

Grassland tillage, which releases considerable quantities of GHG emissions, also has an impact on agricultural GHG emissions. Grassland's share of agricultural land in Germany used to be decreasing continuously. Since 2016, it has levelled off at 26 %, however. In 2020, about 5 million ha in Germany were being used as permanent grassland (cf. also Umweltbundesamt, 2022 NIR).

The federal governments Climate Action Programme 2030 was adopted in 2019, for the purpose of implementing the country's Climate Change Act and its Climate Action Plan. For the agriculture sector, the Programme contains five concrete measures for achieving the sector's climate goal by 2030:

- Reducing nitrogen surpluses, including reducing ammonia emissions and nitrous oxide emissions, and improving nitrogen efficiency
- Increasing digestion of animal-based farm manure and of agricultural crop residues
- Expanding organic farming
- Reducing emissions from animal husbandry
- Improving energy efficiency in agriculture

Currently, a new immediate-action programme for achieving the sector's more-ambitious climate goal is planned.

2.12 Forestry

2.12.1 Structure

Pursuant to the first comprehensive survey of forestry-sector structures, Germany had about 10.2 million ha of forest land in 2022.[101] 4.4 million ha, or 43 % of the total forested area, are privately owned. The total number of private forest owners is about 760,000. About 3.3 million ha of state forest (32 %) are managed by the competent forest administrations of the German states (Länder). A total of 2.2 million ha (22 %) of the forested area is allocated to local authorities (bodies governed by public law, such as special-purpose associations, and municipalities). Federally owned forest land, totalling only 310,000 hectares

[101] German Federal Statistical Office (Statistisches Bundesamt) https://www.destatis.de/DE/Presse/Pressemitteilungen/2022/09/PD22_415_41161.html

(3 %) of the total forested area, accounts for far and away the smallest share of Germany's total forested area.

With annual revenue of 183 billion EUR, and a workforce of about 1 million, the German forestry and wood-products cluster contributes about 2.2 % to the country's overall gross value added. About 90 % of the German wood industry is generated with softwood. The sawmill industry produces some 26 million cubic meters of sawn softwood, but only about 1 million cubic meters of hardwood lumber.[102] Sales of softwood are closely tied to uses in the construction sector. Potential uses for hardwoods are far from exhausted, primarily for technical reasons.

2.12.2 Impacts of forests and forestry on GHG emissions

Carbon / CO_2 emissions and removals on forest land are calculated on the basis of national forest inventories (2002 National Forest Inventory (Bundeswaldinventur – BWI) 2002, the 2008 Inventory Study (Inventurstudie) and the 2017 Carbon Inventory (Kohlenstoffinventur).

For the period 2012 through 2017, the 2017 Carbon Inventory measured carbon removals in biomass amounting to 12.4 million t of carbon per year, along with a carbon-stocks increase (through 2017), of 113.7 tonnes per hectare in forests (Riedel, T., Stümer, W. et al. 2019). Pursuant to the 2017 Carbon Inventory, Germany's forest lands had a total area of 11.4 million ha in 2017, an area equivalent to 32 % of the country's area. In the period covered by the Inventory, 20,000 ha of forest land were converted into other types of land (i.e. non-forest land). The primary types of conversion included development and conversions to agricultural land or permanent grassland. At the same time, 24,000 ha of new forest were created via afforestation or succession, on land that had previously been used as agricultural land or permanent grassland. As a result, the 2017 survey measured a forested area of 11,443,094 ha, which amounted to a slight increase – about 3,000 ha – with respect to 2012 (cf. in this regard T. Riedel, P. Henning, 2019).

In carbon removal (storage), forest land plays a key role as a net carbon sink (-45.8 Mt CO2e in 2020). In the category Forest Land, the most important factors for removals are the pools biomass (56.0 %), mineral soils (30.6 %) and dead wood (7.2 %). The relevant emission sources include (forest-floor) litter, drainage, soil mineralisation and forest fires (accounting for a 6.2 % share of forests' GHG balance).

The sink performance of forests in Germany is trending downward, because the use of wood is increasing, and because biomass growth and carbon sequestration tend to slow in older stands. In addition, calamities that have occurred in the past three years, such as storms, drought and insect infestations, have affected forests' ability to store carbon. The full extent to which forests are so affected will not be known until the analysis results of the current 2022 National Forest Inventory become available.

2.12.3 Impacts of climate change on forests and on the forestry sector

The extent, direction, and speed of current climate change threaten to exceed the ability of forests to adapt. This has become apparent in the forest damage and mass pest infestations that have occurred in recent dry years. Extreme weather events can cause early leaf drop and slow growth. Drought increases the risk of wildfires. At the same time, intensified stress for forests increases the risks of losses via pests such as bark beetles. Mass

[102] https://www.bmel-statistik.de/forst-holz/tabellen-kapitel-g-und-hvii-des-statistischen-jahrbuchs

propagation of pests such as nun moths and cockchafers may occur more frequently, and pests that have previously been unimportant or disregarded may increase. The locations that are at particular risk include locations with a generally poor water supply, unnatural coniferous monocultures at lower elevations, and stands that are not appropriate for other reasons.

Mountain forests in the Alps are particularly affected by climate change. The effects of climate change are stronger there than in lowland areas. Also, the risks of natural hazards (heavy snowfall, mudslides, floods, and falling rock) have been increasing considerably. Such effects and risks are increasingly highlighting the importance of forests for protecting settlements and infrastructure.

Climate change is only one of the multiple stress factors faced by forests, however. Air pollution is another, for example. If warming occurs as expected, and if the frequency and intensity of droughts, and of storms in central Europe, tend to increase, growing conditions will worsen in many locations – especially for spruce. Spruce plays a central role in the German forestry sector. It is the tree species most commonly grown, and it has special economic importance. In recent years, it is the tree species that has suffered most, however, and spruce stands have shrunk overall.

3 Information about the GHG inventory

The descriptions provided in the present Chapter are based on the 2022 National Inventory Report. In April 2022, Germany submitted its most-recent inventory report, along with inventories of its GHG emissions for the years 1990 – 2020 (NIR 2022). The NIR 2022 describes the methods and data sources on which the calculations of German GHG emissions are based. For further details, including details on determination and calculation of emissions for inventory purposes, we refer to the NIR 2022.[103] From 10 to 15. October, Germany's GHG-emissions inventories were reviewed by an international group of experts reporting to the UNFCCC.

The following section presents data on the direct GHG gases carbon dioxide (CO_2), methane (CH_4), nitrous oxide (laughing gas; N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3).

3.1 Determination, structure and presentation of emissions data

Germany's GHG emissions for the years 1990–2020 are presented in summary tables and tables showing trends for specific substances. To highlight changes in emissions, those trends are also presented in graphic form.

Detailed information on annual emissions is presented in a) inventories published annually in the Common Reporting Format (CRF) and b) CTF Table 2 of the 5th Biennial Report. The data used in the present report are in keeping with the emissions data transmitted to the UNFCCC on 14 April 2022.[104]

3.2 Accuracy of emissions data

Uncertainties are a basic component of emissions inventories; an emissions inventory's uncertainties are determined in order to quantitatively assess the inventory's accuracy. While uncertainties are determined in connection with data gathering, and thus are part of the "data collection" section of the emissions-reporting process, they can be aggregated only after an inventory – or the pertinent emissions-reporting cycle – has been completed.

In calculation and aggregation of uncertainties, uncertainties for activity data and emission factors, which are normally estimated by experts at the lowest category level of the CSE (the *Central System of Emissions* database), are converted into uncertainties for emissions and then aggregated. Uncertainties are aggregated once per year, at the end of the report-preparation cycle for the current report year.

For uncertainties determination, the individual uncertainties have been estimated, wherever possible to date, by data-supplying experts of the relevant German Environment Agency specialised sections and by external institutions.

[103] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?list-part=1#articlelist

[104] The CRF Tables of the national GHG inventories are published at: https://unfccc.int/ghg-inventories-annex-i-parties/2022 (cf. Germany – CRF)

The total uncertainty of the inventory for the year 2020, pursuant to Approach 1, is 3.6 %; pursuant to Approach 2, it is -3.2 / +3.5%. The following table provides a concise overview of the uncertainties of the inventory as a whole:

Table 5: Overview of the uncertainties for the inventory as a whole

	Base Year	2020	Trend	Method	Base year uncertainty		2020 uncertainty		Trend uncertainty	
	kt	kt	%		%		%		%	
National total incl. LULUCF	1,272,618	717,473	-43.62	Approach 1	4.47		3.56		3.95	
				Approach 2	-2.97	+3.14	-3.18	+3.45	-9.01	+9.45
National total w/o LULUCF	1,245,615	728,738	-41.50	Approach 1	4.52		3.62		3.35	
				Approach 2	-2.38	+2.59	-2.07	+2.64	-6.56	+7.01

The overview shows the uncertainties for the German inventory as a whole, both with and without CRF 4. For both perspectives, the uncertainties are listed for the base year, for 2019 and for the trend. In each case, the uncertainties have been determined both pursuant to Approach 1 and via use of Monte Carlo simulation (Approach 2). The latter method yields considerably better insights. For example, only Approach 2 uncertainties properly highlight the difference between the two lines (with and without LULUCF).

The CO_2 emissions of the sector Combustion of fuels (1.A) contribute an important share of the total uncertainty. The predominating components of that share include solid fuels in the sector Public electricity and heat production (1.A.1.a) and mobile sources (1.A.3), especially road transport (1.A.3.b) and combustion in the residential and commercial/institutional sectors (1.A.4.a/b/c).

Nitrous oxide emissions overall also contribute significantly to the total uncertainty. This effect is shaped especially by nitrous oxide emissions from manure management (3.B) and from agricultural soils (3.D).

The CO_2 sinks and sources in Sector 4 LULUCF also account for an important share of the total uncertainty.

Methane emissions from animal husbandry (Enteric fermentation, 3.A), and energy inputs in industrial sectors, in areas 1.A.2.a and 1.A.2.g, also make considerable contributions to the total uncertainty.

Detailed information about the applicable sector-specific uncertainties is provided in Annex 7 of the NIR 2022.

3.3 GHG emissions, 1990–2020

In the framework of the second commitment period of the Kyoto Protocol, the countries of the European Union have committed themselves to working together to reduce their greenhouse-gas emissions by 20 % by 2020, with respect to the base year (1990 or 1995[105]). Germany has set itself the national goal of reducing its GHG emissions by at least 40 %, with respect to 1990 levels, by 2020.

On the whole, greenhouse-gas emissions decreased by 41.3 % in 2020.[106] Considerations of the various components involved confirm this trend, to varying degrees. The relevant emissions changes for the most important greenhouse gases in terms of quantity were as follows: -39.2 % for carbon dioxide (CO_2), -58.7 % for methane (CH_4) and -51.4 % for

[105] For HFC, PFC and SF_6

[106] All figures do not include emissions from the category of Land Use, Land-Use Change & Forestry (LULUCF).

nitrous oxide (N_2O). The corresponding trends for the so-called "F" gases, which contribute about 1.7 % of greenhouse-gas emissions overall, have not been as clearly similar to each other, however. In keeping with the introduction of new technologies, and with use of these substances as substitutes, since base year 1995 SF_6 and PFC emissions have decreased, while HFC emissions increased. In total, emissions of F gases have decreased by 28.9 % since 1995, however.

With respect to the previous year, 2019, total emissions decreased by 8.9 %. That reduction was the largest seen since 1990, the year of German reunification.

For the most part, the reduction seen is due to structural changes in the energy industry, as well as to pricing factors such as low gas prices, and high prices for CO_2 certificates (allowances) within European emissions trading.

In addition, CO_2 emissions from electricity generation decreased again in 2020. Use of hard coal and lignite also decreased again. In recent years, use of natural gas has increasingly been supplanting coal in electricity generation, and its specific CO_2 emissions are lower than those of coal. Also, renewable energies' share of electricity generation has increased markedly.

Figure 19 shows the development of GHG emissions in Germany since 1990, in graphic form, both for the individual greenhouse gases involved and for their sum total, expressed as CO_2-equivalent emissions.

In 2020, carbon dioxide emissions again accounted for the largest share of greenhouse-gas emissions – 87.7 %. Most of the carbon dioxide is released via stationary and mobile combustion of fossil fuels. As a result of a disproportionately large reduction of other greenhouse-gas emissions, CO_2 emissions' share of total emissions has increased by about 3 percentage points since 1990. Methane (CH_4) emissions, caused predominantly by animal husbandry, fuel distribution and landfills, accounted for a 6.7 % share. Emissions of nitrous oxide (N_2O), caused primarily by agriculture, industrial processes and burning of fossil fuels, contributed 3.9 % of greenhouse-gas releases. Fluorinated greenhouse gases ("F gases") contributed about 1.7 % to total emissions. The greenhouse gas NF_3, which is now also being reported, is of negligible importance. Furthermore, the low emissions of that substance are confidential in part, meaning that part of the emissions have to be reported elsewhere.

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

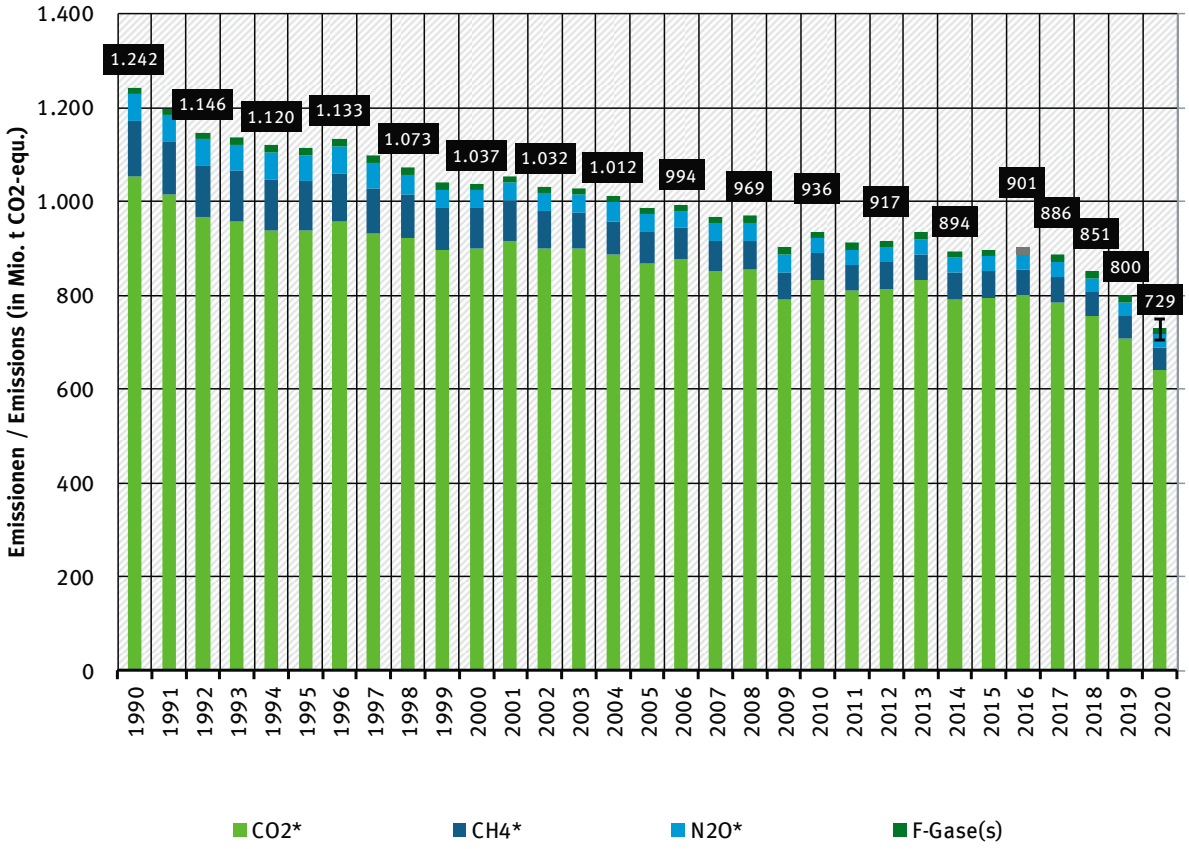


Figure 19: Development of GHG emissions in Germany since 1990, by greenhouse gases; Source: German Environment Agency (2022) [107]

The courses of these developments, with respect to the year 1990, are summarised in Figure 20. In the period under review, considerable reductions were achieved of emissions of direct greenhouse gases, which are important in terms of the quantities involved.

[107] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

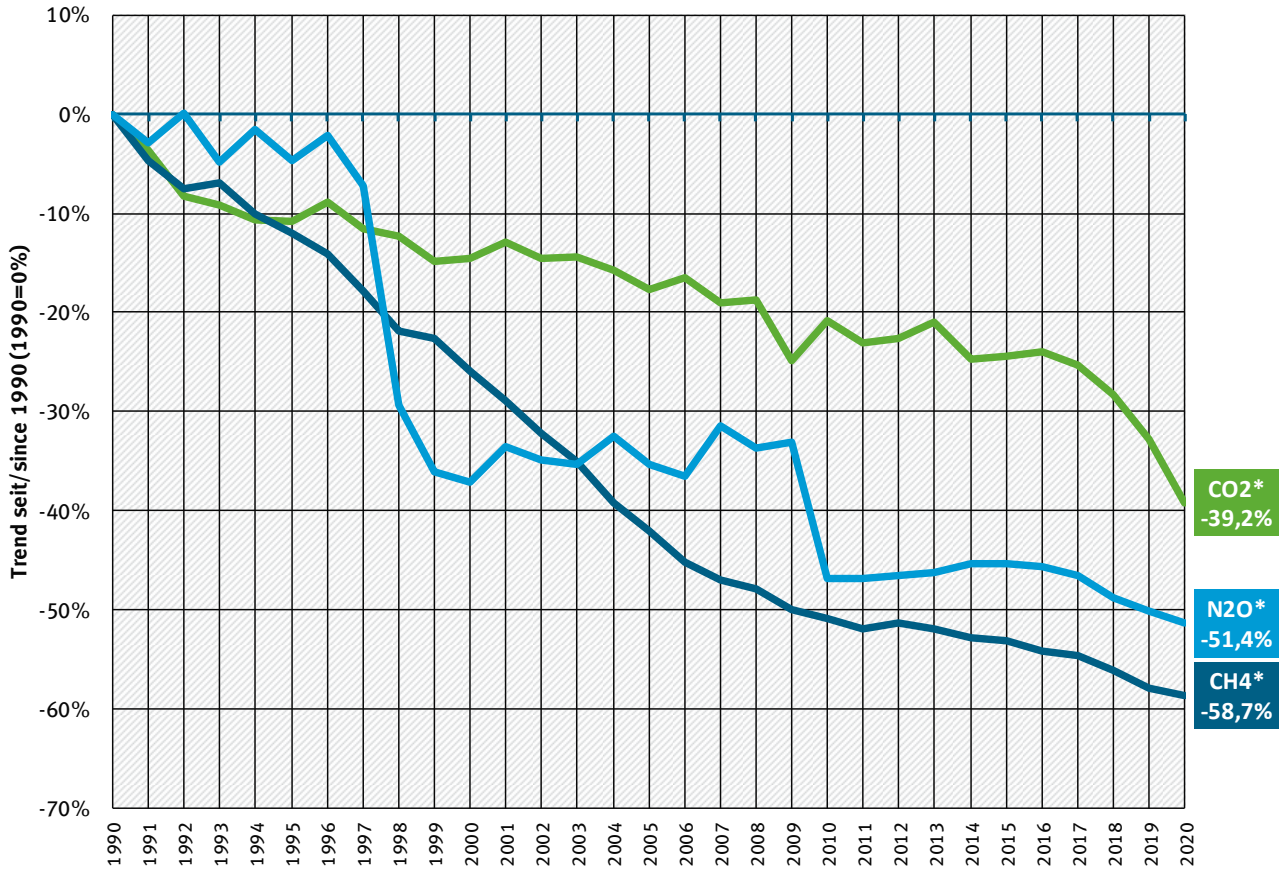


Figure 20: Relative development of greenhouse gases, with respect to 1990 levels, and not including LULUCF; Source: German Environment Agency (2022) [108]

Figure 21 shows the relative developments of emissions, by categories, since 1990. The development of each of these greenhouse gases is shaped largely by specific developments in one category. For example, the reduction in CO_2 emissions is closely linked to trends in the energy sector.

[108] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

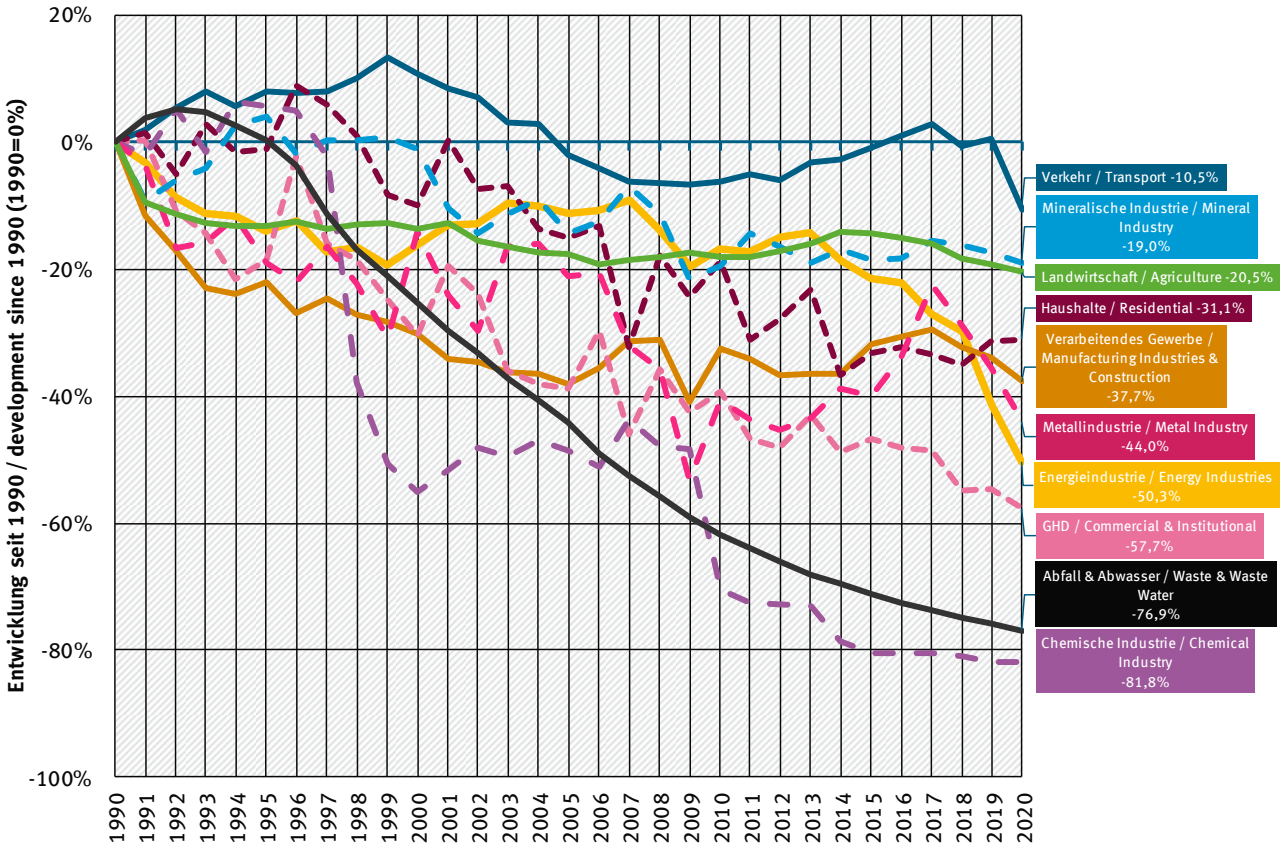


Figure 21: Development of GHG emissions since 1990, by categories; Source: German Environment Agency (2022) [109]

[109] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#arti-clelist

Table 6: Emissions trends in Germany since 1990, by greenhouse gas and category; Source: German Environment Agency (2022) [110]

Emissions Trends	1990 (kt)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
CO_2 emissions (without LULUCF)	1,051,979	938,614	899,352	866,303	832,541	808,912	813,693	831,208	792,255	795,557	800,340	785,616	754,408	707,150	639,381
Net CO_2 emissions/removals	1,076,570	911,628	887,392	867,709	814,811	789,854	784,512	804,688	766,386	771,823	774,608	760,212	730,929	688,886	624,731
CH_4 (without LULUCF)	118,555	104,350	87,798	68,701	58,140	57,051	57,597	56,966	55,847	55,627	54,366	53,798	52,007	49,944	49,015
CH_4 (including LULUCF)	119,996	105,785	89,232	70,292	59,867	58,792	59,355	58,741	57,639	57,438	56,186	55,629	53,953	51,814	50,889
N_2O (without LULUCF)	57,989	55,250	36,483	37,522	30,841	30,855	31,001	31,172	31,705	31,655	31,521	31,028	29,716	28,948	28,182
N_2O (including LULUCF)	58,960	56,211	37,419	38,873	32,150	32,195	32,376	32,582	33,152	33,142	32,967	32,489	31,199	30,450	29,694
F gases, sum (CO_2 equip.) 1995 base year	13,395	17,092	13,293	14,184	14,246	14,426	14,609	14,642	14,657	15,116	15,215	15,288	14,411	13,692	12,159
Total Emissions without LULUCF (CO_2 equi.)	1,241,919	1,115,305	1,036,926	986,709	935,768	911,244	916,901	933,987	894,465	897,954	901,442	885,729	850,542	799,734	728,738
Total Emissions/Removals with LULUCF (CO_2 equi.)	1,268,922	1,090,716	1,027,337	991,058	921,074	895,267	890,853	910,653	871,834	877,519	878,975	863,618	830,492	784,842	717,473
Emission source and sink categories	1990 (kt)	1995	2000	2005	2010	2011	2012	2013	2014	2015	2016	2017	2018	2018	2020
1. Energy	1,036,444	917,379	869,647	831,839	800,987	777,237	783,914	801,247	761,165	766,393	768,977	750,503	720,389	673,836	608,399
2. Industry	96,891	98,600	77,895	75,602	62,559	62,485	61,569	61,319	61,194	60,229	62,076	65,933	62,967	59,790	55,473
3. Agriculture	70,581	61,252	60,997	58,081	57,761	57,844	58,511	59,271	60,547	60,388	59,993	59,311	57,634	56,912	56,095
4. Land-Use Change and Forestry	27,003	-24,590	-9,589	4,348	-14,694	-15,976	-26,048	-23,334	-22,631	-20,435	-22,467	-22,111	-20,050	-14,892	-11,265
CO_2 (net emissions)	24,591	-26,986	-11,959	1,406	-17,730	-19,058	-29,181	-26,520	-25,870	-23,733	-25,732	-25,404	-23,479	-18,264	-14,650
$N_2O + CH_4$	2,412	2,396	2,370	2,942	3,036	3,081	3,133	3,185	3,239	3,298	3,266	3,293	3,430	3,372	3,385
5. Waste	38,003	38,074	28,388	21,188	14,461	13,677	12,907	12,150	11,558	10,943	10,396	9,982	9,552	9,196	8,770

[110] German Environment Agency (Umweltbundesamt 2022): Nationaler Inventarbericht 2022 (National Inventory Report 2022), available at: https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

3.3.1 Carbon dioxide (CO_2)

The reduction in CO_2 emissions is closely linked to trends in the energy sector. The sharp emissions reduction in this area seen in the early 1990s was primarily the result of restructuring in the new German Länder, including related conversions to cleaner fuels and decommissioning of obsolete facilities. The changes in the fuel mix have continued, to a somewhat lesser degree, through 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 CO_2 emissions from liquid fuels decreased by about 48 %, with respect to their levels in 1990, and emissions from solid fuels decreased by about 67 percent, emissions from gaseous fuels increased by nearly 41 percent.

When these emissions trends are viewed at the level of individual categories, a highly consistent picture emerges. In comparison to 1990 levels, emissions in all sub-categories of stationary combustion systems decreased by a total of nearly 371 million t CO_2.

The situation is somewhat different only in the transport sector, which is dominated by road transports: CO_2 emissions in this area increased through 1999, to 184 million t, and then decreased slightly as a result of reductions in consumption, shifting of refuelling to other countries[111], substitution of diesel fuel for gasoline[112] and use of admixtures with biodiesel. In about 2007, the trend began stagnating, at a level of about 153 million t, in part as a result of ongoing increases in average engine power. In the years as of 2013, that stagnation gave way to an upwardly direction, as a result of further increases in transport densities and mileage travelled, and as a result of decreased use of biofuels. This trend peaked in 2017, at a level of 167 million t. Thereafter, emissions decreased again, to a level of slightly more than 160 million t. The level seen in 2020, at 145 million t, lies considerably below the long-term trend, and it is due primarily to various special effects.

With respect to the previous year, CO_2 emissions of the energy sector, which is quantitatively predominant, again fell drastically (by -15.4 %, or nearly 38 million t). Also, emissions of the transport, commercial and institutional (trade, commerce and services), manufacturing and military sectors decreased considerably, primarily as a result of special effects, while those of households increased very slightly.

3.3.2 Nitrous oxide (N_2O)

Since 1990, N_2O emissions have decreased by about 51 %. The main emissions areas/sources include agricultural use of nitrogen-containing fertilisers, animal husbandry and fuel use. Smaller amounts of emissions are caused by wastewater treatment, by the chemical industry and by product use of N_2O (for example, as an anaesthetic). Industry has had the greatest influence on emissions reductions, especially in the area of adipic acid production – via installation of redundant waste-gas-treatment systems in 1997 and 2009. Via technological reduction measures, the chemical industry's emissions have been reduced by 97 %, with respect to 1990. Since 1999, trends in the remaining emissions have been strongly influenced by economic trends in the chemical industry sector.

[111] The emissions are calculated on the basis of domestic fuel sales. Fuel quantities not purchased in Germany thus do not enter into the German emissions inventory.

[112] Diesel fuel's share of total fuel consumption in road transports has increased sharply throughout the entire time period. In 1990, nearly two-thirds of road transport emissions were the result of gasoline consumption. Now, this ratio has nearly been reversed.

Total emissions decreased with respect to the previous year (-2.6 %), especially as a result of further emissions decreases from mineral-fertiliser use in the agricultural sector, which is quantitatively predominant (decreases in that area: -1.6 %)

3.3.3 Methane (CH_4)

Methane emissions are caused mainly by animal husbandry in agriculture, waste landfilling and 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 58.7 % since 1990. This trend has been primarily the result of environmental-policy measures (waste separation, with intensified recycling and increasing energy recovery from waste) that have decreased landfilling of organic waste. A second important factor is that use of mine gas from coal mining, for energy recovery, has increased, while overall production of such gas has decreased (via closure of hard-coal mines). As a result, emissions in category 1.B, Fugitive emissions from fuels, have decreased by more than 85 % since 1990. Yet another reason for the emissions reductions is that livestock populations in the new German Länder 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 of total emissions.

In comparison to the previous year, emissions decreased by 1.9 %. The largest emissions decreases, in quantitative terms, occurred in the areas of landfills, agriculture and fugitive emissions from fuels.

3.3.4 F gases

In 2020, emissions of F gases accounted for only about 1.7 % of total emissions. Since 1995 (the base year for F gases), they have decreased by 29 %. At the same time, the trends for the different individual substances and substance groups involved differ considerably:

HFC emissions increased primarily as a result of intensified use of HFCs as refrigerants in refrigeration and air-conditioning systems and of increasing disposal of such 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 SF_6 emissions reduction that lasted until about 2003 was due primarily to decreasing use of the gas in automobile tyres since the mid-1990s. In this area, efforts to increase environmental awareness have been successful, resulting in emissions reductions of over 100 t and greenhouse-gas reductions of 2.5 million t of CO_2 equivalents. Similar success has been achieved with soundproof windows, for which production use of SF_6 has been reduced to nearly zero since 1995. And a large share of current and future SF_6 emissions (will) result from open disposal of old windows. Emissions from electricity-transmission facilities have also decreased considerably. Important remaining emissions sources include welding, and production of optical glass fibre.

Since 2015, NF_3 has been used in Germany only in semiconductor production. Because those emissions are of such minor importance with regard to total GHG emissions, we have not carried out a separate trend analysis for them.

3.4 National System for inventory preparation

The National System for Germany fulfils the requirements of the Kyoto Protocol and of the European Regulation on a mechanism for monitoring and reporting greenhouse gas emissions in the European Union and its Member States.[113]

The National System provides for the preparation of inventories conforming to the principles of transparency, consistency, comparability, completeness and accuracy. Such conformance is achieved through use of the methodological regulations from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, through ongoing quality management and through continuous inventory improvement.

At the ministerial level, the National System was established under the leadership of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), via an agreement 5 June 2007 signed by state secretaries of the participating ministries that serves as a pertinent policy paper and is entitled "National Emissions Reporting System" ("Nationales System zur Emissionsberichterstattung"). On the basis of that agreement, the National System was institutionalised, in a process that was completed by the year 2011. Initially, this occurred via the establishment of a National Co-ordinating Committee and of pertinent in-house regulations for the German Environment Agency (UBA). Later, institutionalisation was completed primarily via signing of relevant agreements with other federal institutions, with industrial associations and with individual business enterprises. In 2013 and 2014, the National System was adapted to the requirements applying under the second commitment period of the Kyoto Protocol and expanded. In 2022, as part of restructuring of ministerial responsibilities within the federal government, management of the National System passed over to the Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz).

The requirements-conformal institutionalisation and function of the National System has been confirmed by all international reviews carried out to date, including the 2010 and 2016 In Country Reviews.

Single National Entity within the German Environment Agency (UBA)

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In Germany, the National System has been institutionalised, in the main, at three levels: at the federal-government ministerial level, at the level of the German Environment Agency (UBA), and at a level outside of the federal administrative sector.

[113] Regulation (EU) No 525/2013 of the European Parliament and of the Council of 21 May 2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change

With the inclusion of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV); the Federal Ministry of Food and Agriculture (BMEL); the Federal Ministry for Economic Affairs and Climate Action (BMWK); the Federal Ministry for Digital and Transport (BMDV); the Federal Ministry of the Interior and Community (BMI); the Federal Ministry of Finance (BMF); and the Federal Ministry of Defence (BMVg), all key institutions and organisations are now involved in preparing emissions inventories that are in a position to provide high-quality specialised contributions. The policy paper on emissions reporting defines the relevant responsibilities of the various participating federal ministries, and it mandates that the National System is to be built on the basis of existing data streams. Where the data streams are incomplete, the pertinent gaps are to be closed by the responsible ministries, via suitable activities. To support of the reporting process, the participating ministries established a co-ordinating committee.

The "National Emissions Reporting System" policy paper also assigns the German Environment Agency the task of serving as the Single National Entity for Germany. Within the German Environment Agency, the Emissions Situation section has been entrusted with this task. At the level of the German Environment Agency, the Single National Entity integrates other specialised agencies within the National System and coordinates the contributions of the other institutions and organisations involved in emissions reporting. For co-ordination of pertinent work within the German Environment Agency, a working group on emissions inventories was established. For implementation, within the German Environment Agency, of the IPCC guidelines for quality control and assurance, a Quality System of Emissions was established in 2005, via an in-house directive.

The following overview figure shows the structure of the three levels of the National System in Germany.

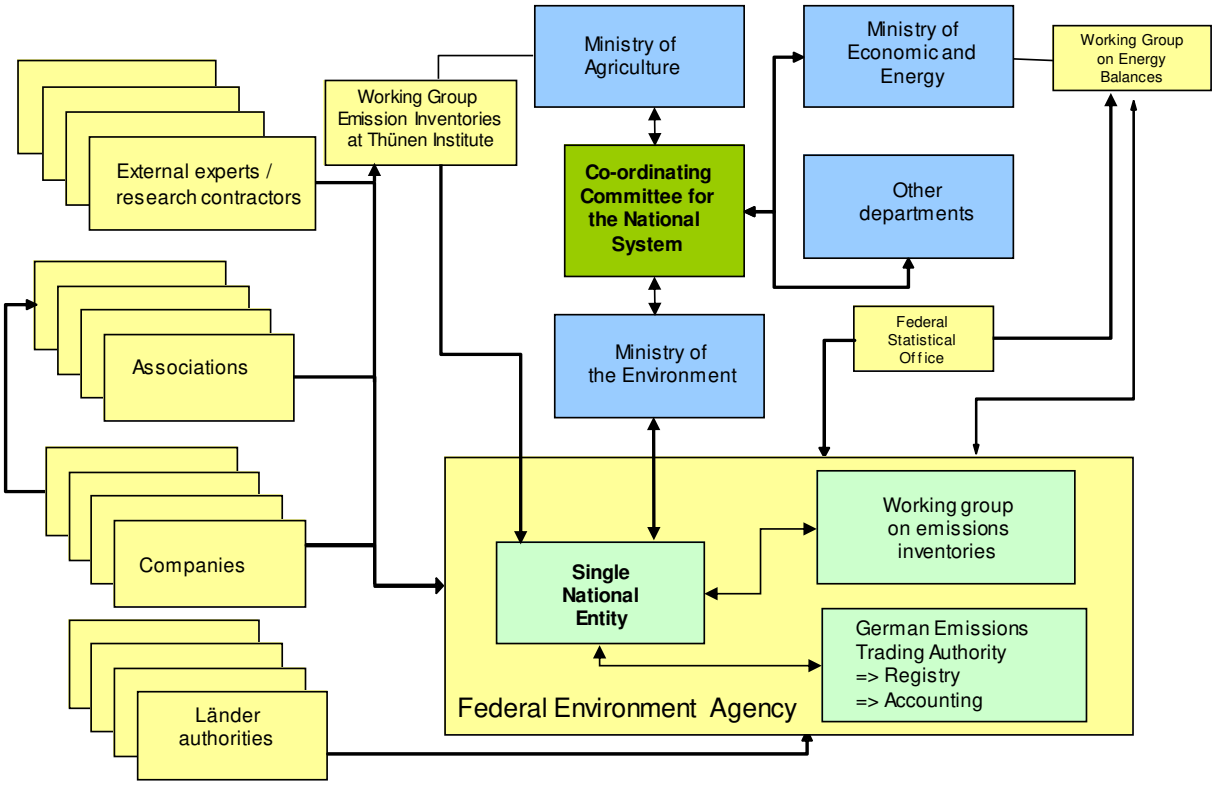


Figure 22: Structure of the National System of Emissions (NaSE); Source: German Environment Agency (2022)[114]

3.5 Description of the National Registries

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 operations of their respective national registries, the EU Member States who are also Parties to the Kyoto Protocol, 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 Regulation (EU) No 389/2013, and of its successor Commission Regulations (EU) 2019/1122 and (EU) 2019/1124, a major re-development of the EU Registry was carried out (a process that was described in detail in the 6th 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.

In June 2012, following the successful implementation of the CSEUR platform, the (then) 28 national registries concerned were re-certified. On 20 June 2012, the re-certified registries were connected to the new system. During the go-live process, all relevant transaction and account data were migrated to the CSEUR platform, and the individual connections to and from the ITL were re-established for each Party.

[114] German Environment Agency (2022): Nationaler Inventarbericht 2022, verfügbar unter (German Environment Agency (2022): 2022 National Inventory Report, available at): https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen?listpart=1#articlelist

4 Policies and measures

The key provisions on governance and goals in connection with German climate policy are laid out in the Federal Climate Change Act (Bundes-Klimaschutzgesetz). This Act, which was adopted in 2019, defines binding national climate action goals, and it provides a legal framework that assures the fulfilment of those goals and compliance with relevant European targets. The key instruments being applied in efforts toward the goals are the federal government's climate action programmes, which comprise measures to reduce GHG emissions and are regularly updated.

4.1 Climate Change Act, and climate goals

In its Climate Change Act, Germany has obligated itself to achieve net greenhouse-gas neutrality by the year 2045. The Act also calls for emissions reductions of at least 65 % by 2030, and of at least 88 % by 2040, with respect to 1990 levels. The Federal Climate Change Act defines a range of maximum permissible annual emission quantities for various different sectors (energy, transport, buildings, etc.), for the period through 2030. The Climate Change Act was adopted in 2019. Originally, it defined a national reduction goal of 55 percent by 2030. In 2021, an amendment of the Act was then adopted that increased the goal to 65 percent.

Via definitions of maximum permissible annual emission quantities for the various sectors involved, the Climate Change Act sets forth the emissions reductions that the sectors have to contribute annually through 2030. For the years 2031 through 2040, it defines cross-cutting annual reduction goals. In 2024, those goals will then serve as a basis for specifying annual permissible emission quantities, for the various sectors, in the 2031–2040 period. Plans call for the federal government to issue, by no later than 2032, a legislative proposal relative to the annual reduction goals in the period 2041 through 2045. Currently, an amendment of the Climate Change Act is being planned that, inter alia, would provide for review of compliance with the climate goals on the basis of a cross-cutting multi-year overall account similar to the approach taken under the Paris Agreement. The basis for such accounting consists of annual monitoring.

For the years 2020 through 2030, the Federal Climate Change Act specifies permissible annual emission quantities for various sectors:

Table 7: Federal Climate Change Act: permissible annual emission quantities for various sectors

Annual emission quantity, in millions of tonnes of CO_2-equivalents	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Energy industry	280		257								108
Industry	186	182	177	172	165	157	149	140	132	125	118
Buildings	118	113	108	102	97	92	87	82	77	72	67
Transport	150	145	139	134	128	123	117	112	105	96	85
Agriculture	70	68	67	66	65	63	62	61	59	57	56
Waste management sector, and other areas	9	9	8	8	7	7	6	6	5	5	4

Section 3a of the Federal Climate Change Act specifies long-term sink goals for the sector Land Use, Land Use Change and Forestry (LULUCF). By the year 2030, the sector must achieve a contribution, in terms of the mean of the annual emissions balances of the respective target year and the three preceding calendar years, of at least 25 million tonnes of

carbon dioxide equivalent per year. By 2040, the average level of carbon sequestration is to be increased to at least 35 million tonnes per year, and by 2045 to at least 40 million tonnes per year. In determination of progress toward the goals, the mean of the annual emissions balances of the respective target year and the three preceding calendar years is used because external influences can cause a sector's sink effect to fluctuate considerably from year to year.

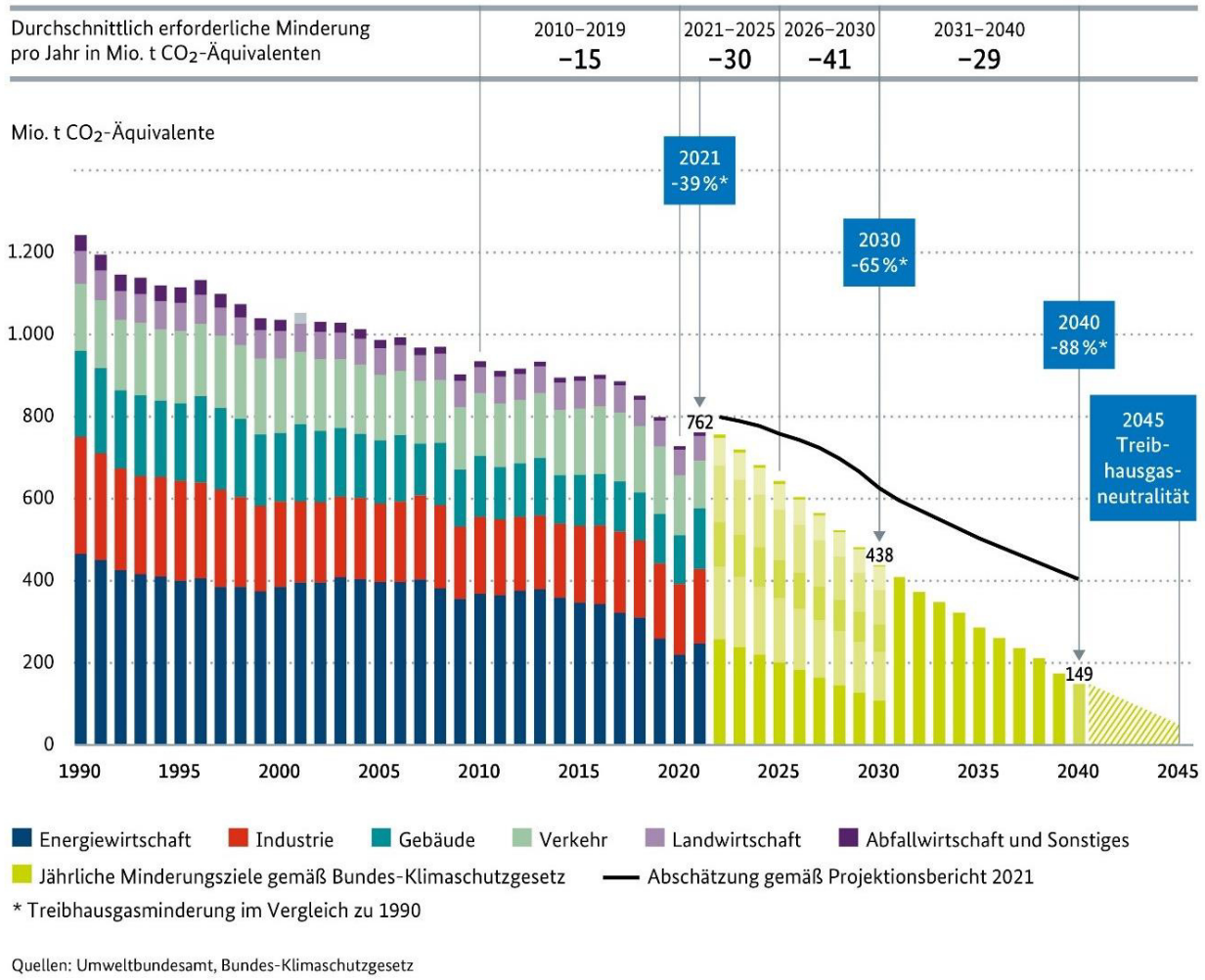


Figure 23: Reduction goals pursuant to the Climate Change Act, and assessment pursuant to the 2021 Projections Report. GHG emissions need to decrease considerably more rapidly than they have in the past. The federal government has adopted a range of additional measures to this end (cf. Chapter 4.4)

4.1.1 Monitoring, and correction if goals are not attained

Compliance with the annual emission quantities, in the various sectors involved, is reviewed on an annual basis. To this end, on 15 March of each year, and making use of the National GHG Inventory, the German Environment Agency publishes the emissions-data estimates for the previous year. If it is determined that a given sector has exceeded its permissible annual emission budget, the federal ministry responsible for the relevant sector is required to propose an immediate-action programme to ensure that the sector will stay within its sector-

specific emission budget in subsequent years. To date, the following required immediate-action programmes have been initiated:

- Immediate-action programme for buildings (Sofortprogramme Gebäude) (July 2021 & July 2022)
- Immediate-action programme for transport (Sofortprogramm Verkehr) (July 2022)

When such measures are needed, the federal government deliberates regarding the measures and adopts them as quickly as possible. In the process, it is supported by the German Council of Experts on Climate Change. The Council reviews the assumptions being made on GHG emissions reduction, via the proposed measures, and then reports accordingly to the federal government. The measures included in the 2022 immediate-action programmes for the areas of buildings and transport are being taken into account in the deliberations on the Immediate Climate Action Programme (Klimaschutz-Sofortprogramm) that are currently being carried out to ensure compliance with the reduction pathways defined by the Federal Climate Change Act (cf. Chapter 4.3.2).

The federal government informs the German Bundestag (lower house of parliament) regarding measures that are adopted.

4.1.2 The German Council of Experts on Climate Change

The Federal Climate Change Act provides for the creation of the German Council of Experts on Climate Change and defines its tasks.

The Council consists of five persons with “outstanding scientific knowledge and experience,” with “at least one member being drawn from each of the fields of climatology, economics, environmental science and social matters.” Council members are appointed by the federal government for terms of five years.

The Council’s tasks include

- Examining the emissions data used for determining compliance with the annual emission budgets, and preparing an assessment of the data for the federal government and the German Bundestag;
- In cases in which a sector exceeds its annual emission budget: Reviewing the assumptions on greenhouse gas reduction that underlie any planned measures, before the draft resolution on measures to be adopted is prepared for the federal government;
- Providing opinions on alterations to or setting of annual emission budgets pursuant to the Federal Climate Change Act, on updating of the Climate Action Plan and on adoption of climate action programmes.
- For the first time in 2022, and then every two years, the Council will submit a report to the German Bundestag and to the federal government on GHG emissions trends to date, on trends pertaining to annual emission budgets and on the effectiveness of reduction measures with regard to compliance with goals defined by the Federal Climate Change Act.

4.2 Climate Action Plan – the long-term strategy

In November 2016, the federal government adopted the Climate Action Plan 2050, the first long-term strategy for climate action in Germany. Since then, development of both the climate policy goals and the governance structures for German climate policy has continued. In particular, a Climate Change Act was adopted in 2019 that specifies binding reduction goals.

The Climate Action Plan 2050 from the year 2016 was described in the 7th National Communication. In fall 2022, acting in light of the fact that Germany's climate policy goals are now considerably more ambitious than the goals specified in that Climate Action Plan, the federal government submitted a concise update of the long-term climate action strategy to the UNFCCC that contains a current overview of Germany's climate goals and important climate policy measures. Plans call for an update of the 2016 Climate Action Plan to be provided in the near future. The long-term climate action strategy is conceived as a learning process. By taking account of new findings and developments – with the help of scientific expertise – it applies a basic philosophy of regular review, ongoing learning and continuous improvement within the meaning of the Paris Agreement.

4.2.1 Science Platform on Climate Protection (WPKS)

In support of its long-term climate action strategy, the federal government has established the Science Platform on Climate Protection (Wissenschaftsplattform Klimaschutz – WPKS), a scientific supporting platform designed to support the country's climate policy in a fundamental, forward-looking and strategic manner. The tasks of the WPKS include supporting the federal government in implementing and refining Germany's long-term strategy for climate action. This includes assessing climate-relevant issues with the help of the WPKS's scientific expertise, providing orientation and decision-making guidance for reviews and updates of the Climate Action Plan, and providing advising relative to evaluating progress. The WPKS's steering committee consists of independent scientists working in a range of different disciplines.

4.3 Climate Action Programmes

In its Climate Action Programmes (pursuant to Section 9 of the Federal Climate Change Act (KSG)), the German Federal Government sets forth the measures that it plans to implement in order to enable Germany to achieve its national climate-protection goals in the various individual sectors involved.

4.3.1 Climate Action Programme 2030

On 9 October 2019, the German Federal Government adopted the comprehensive Climate Action Programme 2030. The key components of the Climate Action Programme 2030 included:

- Introduction of a system for CO_2 pricing in non-ETS sectors,
- Cost relief for citizens,
- Measures in the various sectors (in particular, funding and incentives programmes), to promote climate action.

Originally, the Climate Action Programme defined a national reduction goal of 55 percent by 2030. In 2021, an amendment of the Federal Climate Change Act (KSG) was adopted that increased the goal to 65 percent. Implementation of the comprehensive Climate Action Programme 2030 was initiated in full. The pertinent measures are currently either being implemented, have already been implemented, or are being planned in detail.

4.3.2 Immediate Climate Action Programme

Currently, the federal government is planning to adopt additional emissions-reduction measures, via an **Immediate Climate Action Programme (Klimaschutz-Sofortprogramm – KSSP)**. The measures will be aimed at ensuring compliance with the ambitious reduction pathways set forth in the amended Federal Climate Change Act. In July 2022, the Bundestag and Bundesrat (the lower and upper houses of the German parliament) adopted a first set of measures for accelerating expansion of renewable energies, for accelerating expansion of the electrical grid and for carrying out additional efforts in the electricity sector. Plans call for adoption of additional laws, ordinances and measures under the Immediate Climate Action Programme in the near term.

4.3.3 Monitoring of climate action programmes – climate action report & projection report

Via climate-protection reports, the German Federal Government reports annually on the status of implementation of the country's climate action programmes and on the reduction effects the programmes achieve. Such reports are prepared in accordance with the provisions of Section 10 of the Federal Climate Change Act and forwarded by 30 June to the Bundestag.

Every two years, and by 15 March of the year in question, the federal government reports on projections of GHG emissions, including sources and sinks in the sector Land Use, Land Use Change and Forestry (LULUCF), and on national policies and measures pursuant to Article 18 of the European Governance Regulation. Since 2019, and in this context, pursuant to Section 10 (2) of the Federal Climate Change Act, the federal government annually forwards a climate projection report, containing projections on reduction of greenhouse gas emissions, to the Bundestag. As of the year 2023, the projections in the projection report will also be reported in the biennial progress reports on the integrated National Energy and Climate Plan in keeping with the provisions of Art. 17 of the European Governance Regulation. The integrated National Energy and Climate Plan is a planning and monitoring instrument of the EU and its Member States. The federal government forwards the projection report to the German Bundestag by 31 March of the relevant year.

4.4 Selected current policies and measures

In keeping with the widely differing challenges involved in the different sectors concerned, the Federal Government is relying on a broad range of instruments, including regulatory law, CO_2 pricing, funding programmes, fiscal incentives, advising and various support services aimed at participating stakeholders. The following section presents a few selected pertinent measures that have already entered into force and that are contributing to Germany's compliance with its climate goals.

A comprehensive, systematic and consistent assessment of the reduction effects of the current policies and measures will be provided in the 2023 Projections Report that is currently being prepared. The results of the assessment will be published by 31 March 2023 at the latest. Measures already quantified in the 2021 Projections Report are listed in Chapter 4.5.

4.4.1 Fuel Emissions Trading Act (BEHG)

The national emissions trading system (nEHS) for the heat and transport sectors takes account of emissions from combustion of fossil fuels (especially heating oil, LP gas, natural gas, coal, gasoline, diesel fuel and waste fuels). Unlike the EU Emissions Trading Scheme, the national emissions trading scheme is designed to focus not on direct emitters, as the causers of emissions, but on the upstream trading level, i.e., on the companies that place fuels on the market ("upstream ETS").

A CO_2 price makes use of fossil fuels more expensive, thereby providing incentives to reduce climate-harmful emissions. The relevant proceeds, after deduction of enforcement expenditures, are returned to the public and to businesses – for example, via the elimination of the EEG levy, or via subsidies for transition to climate-friendly alternatives for heating and transport. CO_2 pricing is a central element of climate policy, because it facilitates cost-efficient emissions reductions and helps to prevent rebound effects. Its effectiveness is supported and improved via regulatory provisions and/or funding measures that also provide incentives for transition to climate-friendly technologies.

CO_2 pricing in the form of a national Fuel Emissions Trading system was introduced as of 1 January 2021. Under the Fuel Emissions Trading Act (BEHG), the national CO_2 prices for fossil fuels for heating and transport have been increasing predictably and continuously. In 2021, the effort began with a moderate price of 25 euro per tonne of CO_2, which corresponds to less than 10 cents per litre of fuel or heating oil. In general, the levy for climate-damaging emissions will be successively increased until the year 2025. The relevant emission certificates will be sold at a fixed price and then, as of 2026, auctioned. For the year 2026, a price corridor with a minimum price of 55 euro per emission certificate and a maximum price of 65 euro per emission certificate has been defined. In their coalition agreement, the parties in the federal government have agreed to create a social-compensation mechanism in addition to eliminating the EEG levy ("climate money"), with a view to offsetting the CO_2-price increases in the market phase after 2026 and to promoting acceptance of the market system. The federal government is currently working on implementation of this provision.

4.4.2 Immediate-action package on energy

On 24 June and on 7 July 2022, the German Bundestag (lower house of parliament) adopted what amounts to the most significant set of energy-policy amendments to appear in decades. The measures included amendments of the Renewable Energy Sources Act (EEG), of the Offshore Wind Energy Act (Windenergie-auf-See-Gesetz) and of the Energy Industry Act (Energiewirtschaftsgesetz – EnWG) and other energy-industry laws, and they included the introduction of an Act on space requirements for wind energy (Windenergie-bedarfsflächengesetz). This will accelerate expansion of renewable energies across a wide range of areas. In addition, it enshrines the principle whereby use of renewable energies is in the overriding public interest and supports public security. This, in turn, makes it possible to simplify and accelerate planning and approval processes. As a result, expansion of renewable energies, onshore and offshore, will be taken to a completely new level. By 2030,

so expectations, renewable energies will meet at least 80 % of Germany's gross electricity consumption. A wide range of measures are being taken with a view to promoting expansion of renewable energies. For example, the expansion pathways and tendered quantities in the areas of photovoltaic systems, onshore wind energy and offshore wind energy are being massively increased, with a view to bringing them in line with the new goals. Specifically, plans call for photovoltaic systems with outputs totalling 215 GW, onshore wind energy systems with outputs totalling 115 GW, and offshore wind energy systems with outputs totalling at least 30 GW to be in place by 2030. To enable pertinent implementation, plans call for legally defining the aim of making at least 2 % of Germany's territory available for onshore wind energy use, by 2032. The expansion pathways will be supported by numerous additional individual measures. These will include: provision of new areas for expansion of photovoltaic systems; expansion of municipal participation in connection with onshore wind energy and photovoltaic systems; intensified development of sites with low wind speeds; and improvement of the framework for citizens' energy projects and the framework for expanded use of rooftop photovoltaic systems. The tendered quantities for offshore wind energy projects will be considerably increased, and tendering will also extend to areas that have not been centrally studied in advance. In addition, the network expansion needed for transformation of the electric grid will be considerably accelerated, and the goal of achieving climate-neutrality will be legally enshrined.

4.4.3 Building Energy Law (GEG)

The Building Energy Law (GEG) is to be successively amended. The standards for new construction are to be tightened, in two steps. The requirements pertaining to refurbishments are to be tightened. Ideally, as of 2024, every newly installed heating system will draw 65 percent of its energy from renewable energy sources. Installation of oil-only heating systems will no longer be permitted as of 2026.

4.4.4 KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations

In 2022, the KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations (Bundesförderung für effiziente Gebäude – BEG) were oriented more strongly to renovations. This will enable the available tax monies to be efficiently applied in areas in which the largest climate-protection effects – and, thus, the greatest funding efficiency – can be achieved. Bonuses will be provided for ambitious refurbishments of the most poorly insulated buildings. In the process, emphasis will be placed on replacing fossil-fired heating systems with heat pumps. With regard to new buildings, as of April 2022, support will be available only for buildings meeting demanding requirements that take buildings' entire life cycles into account. This will lead to considerable reductions of emissions tied to the construction, replacement and removal of buildings, in addition to the reduction of buildings' operation-related emissions. New buildings have to meet the KfW 40 (NH) efficiency house standards and qualify for the "Sustainable Building" quality seal (Qualitätssiegel Nachhaltiges Gebäude (QNG)). Funding for new construction is being restructured. A new programme, entitled "Climate-friendly new buildings" ("Klimafreundlicher Neubau"), is refining the quality seal for sustainable construction. In the process, it is placing greater emphasis on consideration of GHG emissions throughout buildings' entire life cycles.

4.4.5 Promotion of electromobility

With still another group of measures, the federal government is moving forward with the transition to electromobility. Through the year 2025, newly registered electric cars will be exempted from vehicle taxation. At most, such exemptions will be granted only through the end of 2030. Furthermore, in taxation of private use of company cars, battery-electric vehicles and plug-in hybrids will be subject to reduced rates through 2030. Since 2016, purchases of electric cars have been subsidised via a guideline on funding sales of electric cars (environmental bonus). This programme is scheduled to run no longer than 2025.

In February 2021, via a funding guideline on electromobility (Förderrichtlinie Elektromobilität), a call for proposals was published relative to procurement, by municipal and commercial fleet operators, of electric cars, lightweight vehicles and special-purpose vehicles, and of the charging infrastructure necessary for operating such vehicles. A further call for proposals, oriented to municipalities, and to procurement of automobiles and lightweight vehicles, was issued in June 2022. In March 2021 and in April 2022, two calls for proposals relative to the development of electromobility concepts were published.

Systematic efforts to expand the charging infrastructure are underway. In October 2022, the federal government adopted a Charging Infrastructure Master Plan II (Masterplan Ladeinfrastruktur II). Efforts to expand the charging infrastructure are being coordinated by a National Centre for Charging Infrastructure (Nationale Leitstelle Ladeinfrastruktur) established in December 2019. Expansion of the charging infrastructure is also being supported via various funding programmes.

Light-duty and heavy-duty commercial vehicles with climate-friendly drive systems are to be made economically competitive with conventional vehicles as soon as possible. A guideline on promotion of commercial vehicles with alternative, climate-friendly drive systems and of the related refuelling and charging infrastructure (Richtlinie zur Förderung von Nutzfahrzeugen mit alternativen, klimaschonenden Antrieben und dazugehöriger Tank und Ladeinfrastruktur – KsNI) is playing a significant role in efforts to reduce added expenditures for procurement of vehicles and required operational infrastructure.

4.4.6 National Decarbonisation Programme for industry

The funding guideline "Decarbonisation in the Industry” (“Dekarbonisierung in der Industrie”) entered into force on 1 January 2021. This funding programme is being managed by the Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (Kompetenzzentrum Klimaschutz in energieintensiven Industrien – KEI). Three projects in the area of climate-friendly glass and chemicals production have already been approved. Funding applications have been submitted for a number of industry projects. And various companies are preparing additional funding applications and project outlines. Currently, the funding guideline is being revised in accordance with the new Climate, Energy and Environmental State Aid Guidelines (CEEAG).

In addition, climate-action contracts are being prepared in keeping with the Carbon Contracts for Differences (CCfD) principle. Such Carbon Contracts help institutions and industry hedge against the higher operational costs entailed in using low-emissions and zero-emissions processes. Also, in the framework of the same programme, the platform *Chemistry 4 Climate* has been established.

4.4.7 Investment programme – Energy efficiency and process heat from renewable energies, in industry

This investment programme has consolidated five existing funding programmes (highly efficient cross-cutting technologies; climate-friendly production processes; prevention and use of waste heat; energy management systems; and renewable process heat) and is developing them further. Expansions to the funding programme including funding for projects focussed on resource efficiency and on transformation concepts. In addition, measures for external (i.e. outplant) waste-heat utilisation will be funded with an increased funding rate, and the funding cap for SMEs has been raised.

4.4.8 Reduction of nitrogen surpluses, including reduction of ammonia emissions and targeted reduction of nitrous oxide emissions; and improvements of nitrogen efficiency

The federal government has already achieved a great deal in this area, via changes in statutes pertaining to fertilisers. These changes have made possible further reductions of nitrogen surpluses, including reductions in ammonia and nitrous oxide emissions. The implementation package for fertiliser legislation includes promotion of low-emissions slurry storage facilities and emissions-reducing spreading techniques.

4.4.9 Promotion of digestion of farm manure and agricultural crop residues

A second important measure has to do with energy recovery from manure and agricultural crop residues, in biogas plants. A range of instruments, including both existing and new ones, is aimed at intensifying use of farm manure in biogas plants and of gas-tight storage of digestates. A new funding system for new systems has been integrated within the funding guideline that entered into force in 2022. In addition, conversions of existing systems are being promoted.

4.4.10 Protection of peatland soils, including reduction of peat use as a substrate in gardening

On 1 Oct. 2021, the federal government published a call for proposals relative to peatland protection. Plans call for comprehensive, practically oriented demonstration of the feasibility of approaches involving farming on rewetted peat (with paludiculture). To this end, about five model and demonstration projects for implementation and assessment of paludicultures on actual plots, with biomass use, are to receive support totalling 100 million euro, over a ten-year period.

The measures for reduction of use of peat as a substrate in gardening, as defined in the “Peat-use-reduction strategy” (“Torfminderungsstrategie”) of the Federal Ministry of Food and Agriculture (BMEL), are being implemented, and existing legal and funding frameworks (CAP; GAEC 2) are being adapted, with such efforts including creation of new funding instruments.

In October 2021, the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the Federal Ministry of Food and Agriculture (BMEL), and the competent Länder ministries, signed the Federal-Länder Target Agreement on Climate Change Mitigation through Peat Soil Conservation (Bund-Länder-Zielvereinbarung zum Klimaschutz

durch Moorbodenschutz). Since 2021, and in a total of four collaborative projects, the federal government has been promoting the further development of an ambitious programme for peat soil conservation. The effort is receiving a total of about 50 million euro over a ten-year period. The pilot projects underway in the programme are aimed at developing innovative strategies for farming and using peat soils. Along with climate protection, they also address issues pertaining to biodiversity, landscape water regimes and socioeconomic aspects related to sustainable use of peatlands.

In November 2022, the federal government adopted the German National Peatland Protection Strategy. This strategy provides the political framework, at the federal level, for all aspects of peatland protection in Germany, and is designed to help Germany achieve climate neutrality by 2045. The strategy's key focuses include protecting all remaining semi-natural peatlands, and restoring and rewetting drained peatlands now being used for agriculture and/or forestry.

4.4.11 Measures for socially equitable transformation

Our climate-protection policy will succeed only if, in addition to achieving real GHG emissions reductions, we also treat economic prosperity and social equity as central policy principles. We have to ensure that burdens are shared in keeping with the polluter-pays principle, and that low-income households are not overstrained. For this reason, the federal government plans to prioritise climate-action measures that contribute equally to climate protection and to social equity. Where alternative, equally efficient climate-action measures are feasible, preference will be given to measures that support social equity and a high employment rate. Where such measures are not available, the federal government will enact downstream measures to safeguard social equity. In their coalition agreement, for example, the parties in the federal government have agreed to create a social-compensation mechanism in addition to eliminating the EEG levy ("climate money"), with a view to offsetting future CO_2-price increases, pursuant to the Fuel Emissions Trading Act (BEHG), in the market phase after 2026 and to promoting acceptance of the market system.

As a result, when CO_2 pricing begins, both industry and consumers will receive relief on their electricity prices. In the years 2021 and 2022, the burdens from the EEG levy were gradually drawn down, and on 1 July 2022 the EEG levy was eliminated altogether.

To prevent social hardship in the face of rising heating and housing costs, additional support will be provided for persons receiving a housing benefit. The law for providing heating-cost relief, for persons receiving housing benefits, and in the context of CO_2 pricing, entered into force on 1 Jan. 2021. Also, as of 1 Jan. 2023, a major reform of the housing benefit system will enter into force that, inter alia, will add a permanent heating-cost component and a "climate" component (to offset rent increases due to energy-efficiency upgrades) to housing benefits. On 25 May 2022, in order to limit landlords' options for passing CO_2 prices on to their tenants, the federal government adopted a draft law on splitting of CO_2 prices: As of 1 Jan. 2023, landlords will be able to pass on only defined portions of CO_2 costs incurred over and above heating costs. To this end, a graduated model will be introduced that will divide up CO_2 costs in accordance with the energy efficiency of the relevant rented building. This will create a double set of incentives: For renters, it will provide incentives for energy-aware behaviour; for landlords, it will provide incentives for investments in climate-friendly heating systems and in energy-efficiency-oriented renovations.

4.4.12 Climate-neutral federal administration

The Federal Climate Change Act (cf. Chapter 4.1) of 2019 calls for the federal administration to set a good example in the area of energy efficiency and to be operating climate-neutrally by 2030. In Feb. 2020, on the basis of a resolution of the State Secretaries' Committee for Sustainable Development, a “Climate-Neutrality Coordination Agency” (“Klimaneutrale Bundesverwaltung” – KKB) was established within the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU). It is charged with coordinating the federal administration’s activities with regard to climate neutrality, advising and supporting government ministries and other institutions in this area, and, in 2023, presenting a “Climate-neutral federal administration” (“klimaneutrale Bundesverwaltung”) programme of measures. At the same time, a range of pilot projects are testing climate-friendly solutions that make use of new approaches. Networking plays an important role in identification of best-practice solutions. For this reason, the KKB regularly organises exchanges with Länder authorities and maintains a range of suitable international contacts.

4.5 Climate-protection policies and measures through August 2020

This chapter describes the measures and instruments that, according to the calculations presented in the 2021 Projections Report, will contribute significantly – either now, or after 2025 – to emissions reduction overall, or in specific sectors. The chapter only covers measures that were adopted through August 2020; i.e. the description reflects the status at that time. For information on an additional selection of measures, including more-recent ones, we refer to the previous chapter 4.4. Some of those more-recent measures are quantified in the 2023 Projection Report, which is scheduled to be published in March 2023.

Every two years, the federal government arranges for determination of future GHG emissions trends on the basis of the climate-protection measures adopted to date. The last projection report, dating from the year 2021[115], describes the development of GHG emissions in Germany in the period 2021 through 2040. The 2021 Projections Report takes account of laws and measures that had been adopted through August 2020 and had already been implemented to an extent that provided the necessary information for modelling. Consequently, measures taken at the EU level, for implementation of the EU’s 2030 climate goal (the “Fit for 55” package), have not yet been taken into account.

The measures descriptions presented here have been taken from the 2021 Projections Report, which also includes reduction effects of individual measures and measures packages. The relevant model system and methods used are described in detail in Chapter 5.2. The sector definitions used in the 2021 Projections Report are in keeping with the national sector definitions used by the Federal Climate Change Act. Allocation of the relevant CRF categories is discussed in the 2021 Projections Report, Chapter 2.1.

Pursuant to modelling for the “with-measures scenario,” the largest emissions-reduction contributions in 2025 will come from the following measures (the reduction effects in 2030 are given in parentheses):

- Act on the Phase-Out of Coal Plants (KVBG): 54 Mt CO2e (114 Mt CO2e)

[115] The 2021 Projections Report has been published on the website of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety: https://www.umweltbundesamt.de/sites/default/files/medien/372/dokumente/projektionsbericht_2021_uba_website.pdf

- Renewable Energy Sources Act (EEG): 33 Mt CO2e (34 Mt CO2e)
- EU emissions trading in the industry and energy sectors: 11.5 Mt CO2e (10.2 Mt CO2e)
- KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations: 6.9 Mt CO2e (12.4 Mt CO2e)
- Revision of the Road Traffic Licensing Regulation to limit HFCs in passenger cars' air conditioning systems, pursuant to the EU MAC Directive (2006/40/EC): 4.622 Mt CO2e (6.1 Mt CO2e)
- Federal support for energy efficiency in the economy: 4.4 Mt CO2e (5.4 Mt CO2e)
- Energy efficiency and climate protection network: 3.6 Mt CO2e) (3.4 Mt CO2e)
- HFC-Phase-Down according to EU F-Gas-Regulation (517/2014) (including Chemicals Climate Protection Ordinance and National Climate Initiative (NCI) funding): 3.5 Mt CO2e (5.7 Mt CO2e)
- National CO_2 pricing of fossil fuels in the heating and transport sectors (BEHG): 3.5 Mt CO2e (7.8 Mt CO2e)
- Building Energy Law (GEG), including prohibition of oil-fired boilers: 3.1 Mt CO2e (4.9 Mt CO2e)

With respect to the 7th National Communication, the following significant changes occurred in the portfolio of measures in the 2017 – 2020 reporting period:

- Amendment of the Renewable Energy Sources Act (EEG)
- Introduction of the Act on the Phase-Out of Coal Plants (KVBG)
- Introduction of BEHG pricing for heating and transport (starting on 1 Jan. 2021)
- EU-CO_2 standards for heavy commercial vehicles
- Promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems

In the following, selected measures providing significant reductions are described, along with their estimated reduction effects. Descriptions of the basic methods used for the relevant calculations and assumptions are provided in Chapter 5.

All quantified instruments and measures are listed in detail in Table 8 (Chapter 4.5.10). The information provided in the table includes, for each measure, the name of the measure, the affected sectors, affected GHG, the type of instrument involved, the current implementation status, the implementing agency and the reduction effects in the years 2020, 2021 and 2025.

4.5.1 Cross-cutting instruments and measures

4.5.1.1 EU Emissions Trading Scheme (PaM O.1)

Since 2005, emissions trading has been the central, cross-cutting measure for CO_2-emissions reduction in Germany. Emissions trading obligates operators of energy generation installations, and of installations in energy-intensive industries, to submit CO_2 allowances for

their CO_2 emissions of the relevant previous year. The scheme covers the gases CO_2, NOx, PFC, N_2O and perfluorocarbons from aluminium production.

Details on the EU Emissions Trading Scheme's third trading period, 2013–2020, are described in the 7th National Communication (PaM 1).

Changes occurring between the 7th and the 8th National Communications

The Emissions Trading Directive's amendments relative to the fourth trading period, 2021–2030, entered into force on 8 April 2018. The amended Directive contains important innovations designed to strengthen EU-ETS and its price signals. Since 2021, the total quantity of emission allowances, including both auctioned allowances and allowances provided free of charge, has been sinking by 2.2 % per year (with respect to the 2010 reference level in each case). Under the Market Stability Reserve (MSR) reform, 24 % – instead of 12 % – of surplus allowances are now being taken out of the market annually until 2023. This higher removal level began in 2019. As of 2023, the maximum size of the Market Stability Reserve will be limited to the quantity auctioned in the previous year. Surpluses over and above that quantity will be deleted from the MSR. In addition, Member States have the option of reducing the numbers of allowances when fossil-fuel power plants are decommissioned via additional national climate-action instruments. Due to the complex interactions taking place at the European level, we are not in a position to carry out our own, solely model-based calculations of the prices for emission allowances (CO_2 price or EUA price). For this reason, we use the EU-ETS's CO_2 prices as given by sector modelling as an exogenic parameter.

Reduction effects

For the energy industry, within the context of the EU Emissions Trading Scheme, the 2021 Projections Report calculates an emissions reduction of 8 Mt CO2e in 2025. In the energy industry, EU emissions trading affects electricity generation in power plants. In other industry areas, EU emissions trading primarily affects energy-intensive sectors such as refineries, metal production and processing, cement and lime production, glass production, ceramics production and paper production. In 2013, the scope of emissions trading was expanded to include additional sectors (primarily in the chemical industry and the non-ferrous metal industry). Also, in some cases (such as adipic-acid and nitric-acid production), it has been expanded to include the greenhouse gas N_2O. In others (such as aluminium production), it has been expanded to include perfluorocarbons. For the industry sector, the 2021 Projections Report calculates an emissions reduction of 3.5 Mt CO2e.

4.5.1.2 CO_2 pricing of fossil fuels in the heating and transport sectors (BEHG) (PaM O.2)

In its Climate Action Programme 2030, the German Federal Government has called for the introduction of CO_2 pricing of fossil fuels in the heating and transport sectors (non-ETS sectors) as of 2021. Such pricing commenced on 1 January 2021. In December 2019, the German Bundestag gave its approval for such CO_2 pricing to be introduced along with the national emissions trading scheme (nEHS) established by the Fuel Emissions Trading Act (BEHG). The nEHS covers emissions from combustion of fossil fuels, including especially heating oil, liquid petroleum gas, natural gas, coal, gasoline and diesel fuel. A system of fixed prices has been introduced for the period through 2025. In 2026, it will be supplanted by a "price-corridor" system. This will provide for the emergence of a reliable price pathway that will enable private households, and businesses, to prepare for the relevant development. The Act primarily affects the areas buildings, transport and industry, which are also the areas for which the effects of this measure have been estimated.

From an initial level of 25 EUR/t in 2021, the CO_2 price will increase successively, to 45 EUR/t[116] in 2025. For the year 2026, a price corridor ranging from a minimum of 55 EUR/t and a maximum of 65 EUR/t will apply. Thereafter, the market will be allowed to determine the price. The basis for this CO_2 pricing in the heating and transport sectors is the "Act on national certificate trading for fuel emissions" (Fuel Emissions Trading Act (Brennstoffemissionshandelsgesetz – BEHG)).

Without a further amendment of the Fuel Emissions Trading Act (BEHG), therefore, for the period as of 2027 price formation in the framework of auctioning of emission allowances has to be unregulated – in keeping with common practice in the EU-ETS. Since at present it is not possible to predict how prices will develop in the market after 2026, without a price corridor, the model calculations were carried out on the basis of the same assumptions, relative to price pathway, that were used for calculations relative to the Climate Action Programme 2030, in the "Politikszenarien IX" ("Policy scenarios") project (Harthan et al. (2020); the long form of the report was published in October 2020): for the period through 2025, the model calculation has been carried out with the price pathway adopted by the mediation committee. For the year 2026, the upper boundary of the price range is assumed. As of 2027, the CO_2 price will be determined by the market, if no maximum and minimum prices are adopted in 2025. For the period after 2027, it is assumed that the price will increase by 15 EUR (nominal) annually, and that it will amount to 275 EUR/t CO_2 in 2040. Because it is not known what inflation-compensation regulations will apply, for modelling purposes the nominal listed values have been adjusted to real prices. Those prices are shown in Table 9.

In addition, in the Fuel Emissions Trading Act (BEHG) Germany has enacted a further control on emissions that fall under the Effort Sharing Regulation (ESR). From the annual ESR emission budgets, the BEHG derives annually permissible fuel emissions that then are subject to the national emissions trading scheme (nEHS). Consequently, the nEHS places prices on the majority of those CO_2 emissions from fuel combustion that are not already subject to the EU Emissions Trading System (ETS). An evaluation of the results for GHG trends under the EU-ETS, ESR and BEHG regimes is provided in section 14.4.

Section 7 (4) BEHG empowers the federal government to define standard values for emission factors of fuels, via ordinances issued without the consent of the Bundesrat. Accordingly, for example, biogenic fuels – if they meet the criteria defined in the ordinances, and are certified as sustainable – may be given an emission factor of zero.

Reduction effects

The reduction effects of the BEHG prices in the sectors transport, buildings and industry amount to a total of 4.6 Mt CO2e. The reductions are broken down and credited for the individual sectors (cf. Chapters 4.5.3.1, 4.5.5.1, 4.5.6.1).

4.5.1.3 Energy and Climate Fund, Energy Efficiency Fund (PaM O.3)

The Energy and Climate Fund (EKF; since 22 July 2022: "Climate and Transformation Fund" (KTF)) was described in the 6th and 7th National Communications. The Creation of a Special Energy and Climate Fund Act (Gesetz zur Einrichtung eines Sondervermögens "Energie- und Klimafonds" – EKFG) of 8 December 2010 (Federal Law Gazette I p. 1807) provided a financial framework for the implementation of energy-policy and climate-policy measures. Since 2012, following decisions by the federal government on 6 June 2011 to

[116] For its calculations, the 2021 Projections Report uses the old value of 55 EUR/t CO_2, in keeping with an amendment from October 2020.

accelerate the Energiewende, Germany's transition to a new energy era, the KTF/EKF has received all proceeds from auctions of greenhouse gas allowances (after deduction of the costs of the German Emissions Trading Authority). In the reporting period, the EKF also received a budget subsidy from the federal budget. As of budget year 2016, the KTF/EKF includes implementation of the additional energy efficiency measures agreed on 1 July 2015 and of the National Action Plan on Energy Efficiency (NAPE). Since 2018, it also includes implementation of large portions of the Immediate Action Programme for Clean Air (Sofortprogramms Saubere Luft).

Changes occurring between the 7th and the 8th National Communications

As of budget year 2020, the KTF/EKF is the central instrument for implementation of the Climate Action Programme 2030 of 9 October 2019. The Second Act for Amendment of the Creation of a Special Energy and Climate Fund Act (EKF) of 12 July 2022 takes the EKF a step further, converting it into the Climate and Transformation Fund (KTF). In the process, the Special Fund's name and purpose have been adjusted with a view to orienting the Fund more effectively and flexibly to the climate goals of the Climate Change Act and to focussing it on measures able to move Germany's transformation to climate neutrality forward.

Reduction effects

As a result, the EKF/KTF serves as an overarching measure that provides the financial framework for implementation of numerous measures in the various individual sectors. Assessment of the effects of such EKF/KTF-financed measures has been carried out for the various relevant sectors. The effects have not been separately quantified and thus are not listed in Table 8.

4.5.2 Energy industry

4.5.2.1 Renewable Energy Sources Act (EEG 2021) (PaM E.1)

The Renewable Energy Sources Act (EEG) was described in the 7th National Communication. The aim behind the EEG 2021 is to enable the renewably generated share of Germany's gross electricity consumption to increase to 65 % by the year 2030. On 1 Jan. 2023, it will be supplanted by the EEG 2023, which sets considerably more-ambitious goals (cf. Chapter 4.4.2).

Changes occurring between the 7th and the 8th National Communications

In addition, the amendment of the EEG that entered into force on 1 Jan. 2021 ("EEG 2021") enshrines the aim of making all of Germany's electricity GHG-neutral prior to the year 2050. This applies both to electricity generated in Germany and to electricity used in Germany. Plans also call for the renewable-energies expansion needed for the achievement of this aim to be continuous, cost-effective and network-compatible. To enable the achievement of the 65 % goal in the year 2030, expansion pathways for installed capacity have been defined, as two-year steps, for the technologies onshore wind energy and solar systems. For onshore wind energy, the resulting expansion goals are 57 GW (2022), 62 GW (2024), 65 GW (2026) and 68 GW (2028); for solar systems, they are 63 GW (2022), 73 GW (2024), 83 GW (2026), 95 GW (2028) and 100 GW (2030). For biomass systems[117], the expansion

[117] Pursuant to the Climate Action Programme 2030, the maximum quantity of biomass available for bioenergy currently amounts to about 1,000 to 1,200 PJ/a (domestic potential). Expansion of the cultivation area for bioenergy crops is not likely, and it should not be expected, given the land restrictions that apply.

goal is 8.4 GW (2030), while for offshore wind energy the expansion goals are 20 GW (2030) and 40 GW (2040). Progress toward those goals is to be assured via an electricity-quantity pathway, defined in one-year steps for renewably generated electricity, and a monitoring and correction mechanism based on that pathway. That mechanism will also make it possible to adjust the relevant technology-specific expansion pathways in cases in which an increase of gross electricity consumption is forecast.

Reduction effects

In the EEG context, the 2021 policy scenarios calculate an emissions reduction of 33 Mt CO2e for the year 2025.

4.5.2.2 Act on the Phase-Out of Coal Plants (KVBG) (PaM E.2)

For 31 Dec. 2022, 1 April 2030 and – as a latest date – 31 Dec. 2038, the KVBG defines specific target levels for the installed capacity of coal-fired power plants, broken down by the fuels hard coal and lignite. In years without a defined target level, reductions of the installed capacities (for both hard coal and lignite power plants) remaining on the market are to take place in equal-size steps overall. The latest shutdown times for the installed capacity of lignite-fired power plants > 150 MW are set forth in the framework of the law. The annual target levels for lignite-fired power plants < 150 MW, and for hard-coal power plants with capacities of at least 10 MW, result as the difference between a linear-degressive target pathway – and taking account of the target levels of the target data of 2022, 2030 and 2038 – and the decommissioning list pursuant to the Act on the Phase-Out of Coal Plants (KVBG) for lignite-fired plants. To achieve those target levels, lignite-fired power plants will be decommissioned in keeping with a legally defined decommissioning list, with plant operators receiving compensation for the early decommissioning of the plants they operate. In cases involving decommissioning of hard-coal-fired power plants and small lignite-fired power plants, the amount of the compensation will be determined via a tendering/auctioning process in which the plant operators offer to decommission the plants in return for a payment (offer). For implementation of the measure in the “with-measures” scenario of the 2021 Projections Report, on the basis of the parameters for regulatory decommissioning, and taking account of other decommissioning options (in particular, decommissioning in the framework of a) CHP-substitutions of coal-fired plant capacity, under the Combined Heat and Power Act (KWKG), and of b) auctioning of capacities of hard-coal-fired power plants), the installed capacities of lignite-fired and hard-coal-fired power plants available in every year between 2021 and 2040 will be estimated, on a by-plant basis. The following applies for hard-coal-fired plants: Beginning in the year 2024, if the target levels aimed for via auctioning of capacities of hard-coal-fired power plants are not attained, plant decommissioning will take place by order (i.e., decree). Such decommissioning will take place in the order of the plants’ ages, with recent modernisations being considered in the determination of that order. Small plants with capacities below 150 MW will be decommissioned, via regulatory law, no earlier than 2030.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the Act on the Phase-Out of Coal Plants (KVBG) will amount to 54 Mt CO2e in 2025.

4.5.2.3 Promotion of innovative district heating network measures (PaM E.3)

Since 1 July 2017, in the framework of the funding programme “Promotion of innovative district heating network measures” (“Wärmenetzsysteme 4.0”), the federal government has

been promoting the construction of innovative district heating networks (4th generation heating networks) for sustainable heating of residential and non-residential buildings, and for provision of low-temperature heat for industrial processes. The funding programme was amended in early 2020. In the process, some eligibility requirements for heating systems were relaxed, with the result that the programme can now be expected to yield a higher number of constructed heating network systems. On 15 September 2022, the “Promotion of innovative district heating network measures” programme was supplanted by the more-ambitious programme “Federal funding for efficient heating networks” (Bundesförderung für effiziente Wärmenetze” – BEW).

For the “with-measures” scenario of the 2021 Projections Report, it is assumed that efforts must focus especially on projects in the areas of solar thermal energy, heat pumps and waste-heat utilisation, as well as on reducing heat losses in existing networks.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the “Promotion of innovative district heating network measures” funding programme will amount to 0.57 Mt CO2e in 2025.

4.5.2.4 EU Emissions Trading Scheme (PaM I.1)

The EU Emissions Trading Scheme is described in detail in Chapter 4.5.1.1. In other industry areas, EU emissions trading primarily affects energy-intensive sectors such as refineries, metal production and processing, cement and lime production, glass production, ceramics production and paper production. In 2013, the scope of emissions trading was expanded to include additional sectors (primarily in the chemical industry and the non-ferrous metal industry). Also, in some cases (such as adipic-acid and nitric-acid production), it has been expanded to include the greenhouse gas N_2O. In others (such as aluminium production), it has been expanded to include perfluorocarbons.

The EU-ETS also covers CO_2 emissions from industrial processes (such as cement and lime production). In early 2013, N_2O emissions from adipic-acid and nitric-acid production, and from production of glyoxal and glyoxylic acid, were included in EU emissions trading.

Reduction effects

For the industry sector, within the EU Emissions Trading Scheme, the 2021 Projections Report calculates reduction effects amounting to 3.5 Mt CO2e.

4.5.2.5 Energy management and discount for industry (Renewable Energy Levy) under the Renewable Energy Sources Act (EEG) (PaM I.3)

The Renewable Energy Levy, an instrument known as “BesAR” (Besondere Ausgleichsregelung), is described in detail in the 7th National Communication (PaM 13).

Via this instrument, and within the context of energy/electricity taxation, manufacturing companies receive tax relief in the form, inter alia, of a tax discount (Spitzenausgleich). Granting of the tax discount is contingent on fulfilment of two prerequisites:

- The applicant company must prove that it will have an energy management system pursuant to DIN EN ISO 50001, or an environmental management system pursuant to EMAS, in place by no later than the end of the year in which the application is being submitted (SMEs may, alternatively, introduce and operate systems for improving their energy efficiency within the meaning of the Ordinance on Systems to improve

energy efficiency in connection with reduction/exemptions from energy and electricity taxes in special cases (Spitzenausgleich-Effizienzsystemverordnung – SpaEfV), which entail less-demanding requirements).

- The energy intensity of manufacturing companies in Germany overall has to decrease by a legally mandated target value. For the reference years 2013 through 2015 (application years 2015 through 2017), the target value amounts to 1.3 % annually. For the reference years as of 2016 (application years 2018 through 2022), it amounts to 1.35 % annually.

Currently, Germany is carrying out a legislative process aimed at extending the tax discount, with a view to supporting energy-intensive companies in the context of the high energy prices prevailing at present, and to ensuring that the energy supply remains affordable.

Reduction effects

The 2021 Projections Report analyses the effects of the tax discount via a consolidated perspective that brings together the Energy Taxation Act (Energiesteuergesetz), the Electricity Tax Act (StromStG) and the energy management and discount programme for industry (Renewable Energy Levy – BesAR). Pursuant to the Projections Report, the reduction effects will amount to 2.9 Mt CO2e in 2025.

4.5.2.6 Energy Advice for SMEs (PaM I.7)

The BMWi programme “Energy Advice for SMEs” (Directive on the funding of energy advice for SMEs” (“Richtlinie über die Förderung von Energieberatungen im Mittelstand”) of 11 Oct. 2017, BAnz AT 07.11.2017 B1, (EBM)) offers small and medium-sized enterprises (SMEs) funding for quality energy advising. In the programme, highly qualified energy advisers identify potential for energy saving in companies and prepare relevant concrete proposals for them. The proposed measures can include concepts for making use of waste heat, for example. The directive conforms to the EU requirements for energy audits pursuant to the EU Energy Efficiency Directive (2012/27/EU). The programme is being administered by the Federal Office for Economic Affairs and Export Control (BAFA). The maximum funding available per measures concept is 6,000 euro.

Improvements in material efficiency hold great potential for reducing the energy consumption of industrial processes in companies and throughout value chains. For this reason, efforts are being made to intensify funding of energy advising in the area of material efficiency aimed at enhancing the energy efficiency of industrial processes. Further training courses focussing on energy-saving via material and resource efficiency are now being accredited in the framework of the training catalogue for energy-efficiency experts for the Federal Government's funding programmes for energy-advising programmes. These activities are also helping to implement Measure 29 of the German Resource Efficiency Programme III. The goals of this Measure include a) enhancing coordination, in terms of both content and structure, of energy-advising services relative to material and energy efficiency, and b) preventing duplication of advising services.

The effects of the measure are being quantified on the basis of the available annual funding that is regularly being updated to meet future needs. In the process, parameters – as determined via external evaluation of the programme – relative to achieved energy savings are also taken into account.

As of January 2021, the programme “Energy consulting for non-residential buildings of municipalities and non-profit organisations” (“Energieberatung für Nichtwohngebäude von

Kommunen und gemeinnützigen Organisationen") has been consolidated with the programme "Energy advice for SMEs" and with contracting-related orientational consulting, within the funding programme "Energy consulting for non-residential buildings, facilities and systems" ("Energieberatung für Nichtwohngebäude, Anlagen und Systeme") (EBN). The pertinent funding continues to cover advising relative to the DIN 16247 and DIN 18599 standards, up to a maximum grant level of 80 %.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the "Energy Advice for SMEs" programm will amount to 0.8 Mt CO2e in 2025.

4.5.2.7 Federal Support for Energy Efficiency in the Economy (PaM I.4)

This programme is a reorganised version of a number of earlier funding measures. The programmes Funding highly efficient cross-cutting technologies (7th National Communication; PaM 14), Funding guideline for promoting the prevention and utilisation of waste heat (7th National Communication; PaM 18), Funding for energy-efficient and climate-friendly production processes (7th National Communication; PaM 15), Funding of energy management systems and Funding of renewably generated process heat, in the context of a market incentive programme, ended as of December 2018 (at the latest). In Jan. 2019, they were then relaunched with adjusted funding conditions and rates, in the form of a joint funding package. In the process, the programmes were consolidated into four modules, and their application procedure was simplified. The restructuring was aimed at creating a holistic range of energy-efficiency funding programmes for industry, at doing away with application barriers and at eliminating overlapping between different measures.

The new funding programme "Federal support for energy efficiency in the economy" ("Bundesförderung für Energieeffizienz in der Wirtschaft") offers funding in four selectable and combinable modules:

- Module 1: Cross-cutting technologies
- Module 2: Process heat from renewable energies
- Module 3: Instrumentation and control engineering (MSR technology), sensors and energy management software
- Module 4: Energy-related optimisation of systems and processes.

Quantification for this measure is carried out bottom-up, on the basis of parameters obtained via evaluation of predecessor programmes and of the planned funding.

Reduction effects

Pursuant to the 2021 Projections Report, the programme "Federal support for energy efficiency in the economy – grants and loans" will achieve GHG reductions of 4.37 Mt CO2e as of the year 2025. This assessment is based on measures implemented in the period 2021 through 2030, and it does not include measures from the predecessor programmes.

4.5.2.8 Energy efficiency and climate protection networks (PaM I.5)

"Energy efficiency networks" are alliances of companies that set common energy-efficiency and GHG-reduction goals and seek to learn from one another in this context. This instrument is described in detail in the 7th National Communication (PaM 17).

Changes occurring between the 7th and the 8th National Communications

In 2020, the agreement for the “Energy efficiency networks” programme was renewed, and its focus was expanded to included climate protection.

The agreement renewed in September 2020 is expected to yield 300–350 additional networks, by 2025, that will produce a total of 9-11 TWh of final energy and save an additional 5–6 million t CO_2-eq. As of 31 Dec. 2019, 250 networks were registered in the programme (as of 9 Oct. 2020: 282 networks), and the aimed-for emissions savings are expected to be achieved, according to the initiative. Quantification for this measure is carried out bottom-up, on the basis of parameters obtained via monitoring of the networks and on the basis of the number of networks involved and their sizes. On 14 September 2020, the Federal Ministry for Economic Affairs and Energy (BMWi) and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), working in cooperation with 21 industry associations and organisations, agreed to continue the “Energy efficiency networks” initiative and to develop it further. In Jan. 2021, the initiative was then launched in its further-developed form, as a programme for energy efficiency and climate protection networks.

Reduction effects

Energy efficiency networks in the trade, commerce and services sector have the potential to reduce power consumption by 0.3 TWh and to reduce direct GHG emissions from fuel use by 0.12 Mt CO2e by 2025. In the industry sector, the networks will achieve electricity savings of 2.9 TWh and emissions reductions (via avoided fuel use) of 3.72 Mt CO2e.

4.5.2.9 Energy audits for non-SMEs (Implementation of Art. 8 EED) (PaM I.6)

This section considers the provisions of Article 8, (4) through (7), of the EU Energy Efficiency Directive (2012/27/EU; EED), which obligate “non-SMEs” to carry out energy audits. The energy audits in the affected companies are to be carried out by qualified and/or accredited experts. Also, the Directive requires the companies to carry out their first energy audit by no later than 5 December 2015. These requirements were transposed via suitable amendments of the Energy Services Act (EDL-G) with effect as of 22 April 2015. Under the requirements, large companies (non-SMEs, i.e., companies that do not fall within the European Commission’s SME definition (< 250 staff headcount, or turnover < 50 million euro, or balance sheet total < 43 million euro)) are obligated to carry out an energy audit pursuant to DIN EN 16247-1 by 5 December 2015 and thereafter to carry out additional audits at least every four years. Companies that have an energy management system certified pursuant to DIN EN ISO 50001, or that have an Eco-Management and Audit Scheme (EMAS) in place, are exempted from the obligation to carry out energy audits.

As part of an amendment made in 2019, a de minimis threshold of 500 MWh total energy consumption was introduced. Companies operating below that threshold may carry out simplified energy audits in the form of a declaration, submitted to the Federal Office of Economics and Export Control (BAFA), on their energy consumption and energy costs. In addition, energy-audit declarations may be completed online. Online declarations include information on the relevant company, on its energy auditor, on its energy consumption, on any proposed energy efficiency measures, and on the costs for the energy audit.

For assessment of the measure’s effects, we rely on a relevant evaluation pursuant to the Energy Services Act (EDL-G) (Adelphi and IREES 2017). In that evaluation, a sample survey of companies obligated under the EDL-G was carried out. In each case, the survey covered both a) the potential identified in the framework of audits and the EMS and b) the measures that were implemented. The measure’s estimated effects as presented here, however, relate solely to measures that were identified in the framework of audits or an

EMS and have not yet been identified. The effects of the EMS are allocated to the measures “tax discount” (“Spitzenausgleich”) and “Energy management and discount for industry (Renewable Energy Levy)” (“Besondere Ausgleichsregelung”).

Reduction effects

The 2021 Projections Report calculates the reduction effects of the energy-audit obligation for non-SMEs in the industry and trade/commerce/services sectors. The instrument’s total effects amount to 2.15 Mt CO2e in 2025. These break down as follows: In the industry sector, the energy-audit obligation for non-SMEs leads to reduction effects of 1.8 Mt CO2e; in the trade/commerce/services sector, it yields reduction effects of 0.35 Mt CO2e.

4.5.2.10 KfW Energy Efficiency Programme (PaM I.8)

In its Energy Efficiency Programme, the KfW grants soft loans to companies, for implementation of energy efficiency measures. The programme promotes those energy-efficient production systems / processes, including cross-cutting technologies, that offer the highest energy-saving potential, relatively speaking. In an updated version of the programme, a new entry-level standard (10 % savings) and a new premium-level standard (30 % savings) were introduced. With this approach, the funding intensity is oriented to the size of the energy savings achieved, and not to the company’s size. Projects meeting the premium-level standard receive especially favourable terms. The improved funding conditions became effective in July 2015. In 2019, a total of 219 commitments were made, with a total funding volume of 974 million euro. The programme is financed via the KfW’s own funds. Quantification of the programme is based on the number of funding cases involved in recent years, and on the relevant funding granted. Both statistics will be updated in the coming years.

Reduction effects

According to the 2021 Projections Report, the reduction effects of the KfW Energy Efficiency Programme will amount to 0.194 Mt CO2e in 2025.

4.5.3 Industry (not including industrial processes and product use (fluorinated greenhouse gases)

4.5.3.1 CO_2 pricing for heating and transport (BEHG pricing) (PaM I.2)

Along with sector-specific measures, cross-cutting introduction of CO_2 pricing in the area of heat generation and transport (cf. Chapter 4.5.1.2), in the framework of the national emissions trading scheme (nEHS), also has an effect on the industry sector’s emissions as presented in the 2021 Projections Report. For industry, this means that fossil-fuel emissions sources not yet covered by the EU Emissions Trading System (EU-ETS) receive a price signal that provides incentives for emissions reductions. The expected effects result via price-driven competition among technologies for heat generation: as CO_2 emissions become more expensive, climate-friendly technologies become more attractive. Between 2021 and 2025, emission certificates are being issued at an increasing fixed price; after that period, they will be traded in the context of a limit on their quantity. After a transition period lasting through 2026, in which a price corridor applies, prices will be allowed to develop freely on the market.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of CO_2 pricing (BEHG) in the industry sector will amount to 1 Mt CO2e in 2025.

4.5.3.2 Package of measures: Market launch of low-carbon processes (PaM I.9)

Measures that promote research and development into low-CO_2 processes, and the market launch of such processes, are quantified as packages of measures, because the technologies they promote overlap to a high degree. This means that measures' effects are listed as part of the effects for the entire package, and not separately, on a single-measure basis. The package of measures consists of the following programmes:

EU-ETS Innovation Fund: Further development of the NER 300 programme

The NER 300 programme, which has been underway since 2011, within the EU-ETS framework, promotes investments in innovative low-CO_2 demonstration projects in the energy industry. The NER 300 programme's main funding focuses are on innovative renewable energy technologies and on Carbon Capture and Storage (CCS). The existing programme has now been updated. In future, it will also – under the heading "Innovation Fund" – extend to the industry sector. As of 2021, the Innovation Fund is part of the EU-ETS. From 2020 through 2030, funding is aimed at providing incentives, within the EU, for industry projects that demonstrate projects for innovative low-CO_2 production processes that can contribute significantly to climate change mitigation, including environmentally safe Carbon Capture and Utilisation (CCU) processes. The EU Innovation Fund's first call for proposals was published by the European Commission on 3 July 2020. That call for proposals addresses large projects with an investment volume of more than 7.5 million euro.[118]

Funding programme for decarbonisation in the industry

This measure, part of the Climate Action Programme 2030 (Chapter 3.4.4.8 of the Climate Action Programme 2030), is a funding programme promoting development, demonstration and market launch of innovative climate protection technologies industry. To maximise emissions reductions in the industry sector, one must seek especially to minimise – or even eliminate – the process-related GHG emissions that currently, with the best available technology, are either impossible or extremely difficult to avoid. To this end, the programme is funding central projects in emissions-intensive industries with process-related emissions. The projects should involve application-oriented R&D, commercial-scale trials and broad-based market launch of mature or new technologies. The decarbonisation in Industry funding programme, an effort of the Federal Ministry for Economic Affairs and Climate Action, went into operation on 1 January 2021. The funding programme is being implemented by the Competence Centre on Climate Change Mitigation in Energy-Intensive Industries (KEI), located in Cottbus.

Programm for the mitigation and use of CO_2 in basic materials industries

The focus of this programme, which is part of the Climate Action Programme 2030, in on emissions reduction in basic materials industries. Its key aim is to promote further development, leading toward market maturity, of central process-chain components in the area of Carbon Capture and Storage (CCS) and Carbon Capture and Utilisation (CCU), and thereby to create the necessary technical basis for lasting reductions of process-related GHG emissions in the industry sector. The programme is currently being prepared. For the period between 2020 and 2024, the Special Energy and Climate Fund (EKF) / Climate and Transformation Fund (KTF) provides funding of about 500 million euro for the funding programme.

[118] The EU Innovation Fund's first call for proposals (2020): https://ec.europa.eu/info/funding-tenders/opportunities/docs/2021-2027/innovfund/wp-call/wp_innovfund-2020_en.pdf

National Hydrogen Strategy: Pilot programme for Carbon Contracts for Difference

In the framework of the National Hydrogen Strategy, a pilot programme for Carbon Contracts for Difference (CCfD) has been approved that will initially focus on the steel, ammonia, cement and lime industries with process-related emissions. In the efforts, the Carbon Contracts for Difference are designed to hedge, by focussing on the difference to the pertinent CO_2 price, against the higher operational costs tied to innovative climate protection technologies. From 2022 through 2024, funding in the amount of 550 million euro is available for the pilot programme. Its effects are being quantified in the context of the industry sector.

National Hydrogen Strategy: IPCEI

The National Hydrogen Strategy also provides for the creation of “Important Projects of Common European Interest” (IPCEI) in the area of hydrogen technologies and systems. Its effects are being quantified in the context of the industry sector.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the package of measures for market launch of low-CO_2 processes will amount to 1 Mt CO2e in 2025.

4.5.4 Industry: Processes and product use (fluorinated greenhouse gases)

4.5.4.1 Limitations on HFCs in car air conditioning systems, pursuant to the EU MAC Directive (2006/40/EC) (PaM I.10)

EU MAC Directive 2006/40/EC (mobile air conditioning) defines maximum GWP (greenhouse warming potential) levels for refrigerants used in the air-conditioning systems of new cars and new types of vehicles.

Reduction effects

Pursuant to the 2021 Projections Report, restrictions on HFCs in car air conditioning systems, pursuant to the EU MAC Directive (2006/40/EC), will have reduction effects of 4.662 mt CO2e in 2025.

4.5.4.2 HFC phase-down pursuant to EU F-Gas Regulation 517/2014 (PaM I.11)

This instrument is described in detail in the 7th National Communication (PaM 45).

Changes occurring between the 7th and the 8th National Communications

The F-Gas Regulation was being revised at the time the Projection Report was being prepared. As of the end of 2021, the European Commission was expected to issue a proposal for revising the Regulation that would include necessary adjustments to bring it in line with the Montreal Protocol (Kigali Amendment of 2016) and that could also include further measures in the context of the European Green Deal. Since that revision process has not yet been completed, for years after 2030 the “with-measures scenario” includes a continuation of the quantity restriction applying in 2030, i.e., the value not including foreseen ambitious tighter restrictions.

Reduction effects

Pursuant to the 2021 Projections Report, the HFC phase-down pursuant to EU F-Gas Regulation 517/2014 (including the Carbon Chemicals Regulation & funding under the National Climate Protection Initiative (NKI)) will achieve reduction effects of 3.5 Mt CO2e in 2025.

4.5.4.3 SF_6 prohibitions pursuant to EU F-Gas Regulation 517/2014 (PaM I.12)

With regard to the F-Gas Regulation, see the pertinent remark in 4.5.4.2.

Reduction effects

Pursuant to the 2021 Projections Report, the SF_6 prohibitions pursuant to EU F-Gas Regulation 517/2014 (including its predecessor, Regulation 842/2006) will have reduction effects of 2.233 Mt CO2e in 2025.

4.5.5 Buildings: heating and cooling

4.5.5.1 CO_2 pricing for heating and transport (BEHG) (PaM G.1)

The CO_2-pricing system is described in the section on cross-cutting measures (Chapter 4.5.1.2).

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of CO_2 pricing for heating and transport in the buildings sector will amount to 0.15 Mt CO2e in 2025.

4.5.5.2 KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations (BEG) – Grants and loans (PaM G.2)

The programme Federal Funding for Efficient Buildings (BEG), which is described in the Climate Action Programme 2030, consolidated the federal government's investments-oriented funding programmes in the areas of renewably generated heat and energy-efficient buildings, and it increased their overall funding budget. At the time the modelling was carried out, a resolution on the funding guideline and its budgetary resources was still pending. For the 2021 Projections Report's with-measures scenario, therefore, the following funding programmes, which have since been folded within the BEG, are listed individually:

- CO_2 Building Rehabilitation Programme (7th National Communication; PaM 19)
- Energy Efficiency Incentive Programme (7th National Communication; PaM 20)
- Market Incentive Programme promoting the use of renewable energy technology (7th National Communication; PaM 21).

Reduction effects

According to calculations in the policy scenarios, the Federal Funding for Efficient Buildings (BEG) programme is expected to have reduction effects of 6.9 Mt CO2e through 2025 (not including effects on the transformation sector).

4.5.5.3 Tax incentives for refurbishment measures (PaM G.3)

The Act for implementation of the Climate Action Programme 2030 in tax laws (Gesetz zur Umsetzung des Klimaschutzprogramms 2030 im Steuerrecht) of 21 Dec. 2019, and the Ordinance on energy-efficiency-oriented refurbishment measures (Energetische Sanierungsmaßnahmen-Verordnung – ESanMV) of 2 Jan. 2020, provide tax incentives for

energy-efficiency-oriented refurbishment measures (Sec. 35c Income Tax Act (EStG)). The tax incentives are available for various measures (Sec. 35c EStG provides a complete list) (such as heating-system replacements, and insulation of individual components of buildings' enveloping surfaces) in residential units and buildings in which beneficiaries themselves reside. In 2020, the tax incentives were introduced as an alternative to the relevant existing KfW funding programmes (CO_2 Building Rehabilitation Programme; the KfW programmes for energy-efficiency construction and modernisation ("Energieeffizient Bauen und Sanieren" – EBS) (7th National Communication; PaM 19) and the Market Incentive Programme (MAP) (7th National Communication; PaM 21), i.e., building owners have to choose between the available funding options for their energy-efficiency-oriented measures. As of 1 Jan. 2021, the tax incentives are available as an alternative to the individual measures within the Federal Funding for Efficient Buildings (BEG) programme. The incentives are provided as progression-independent deductions from the taxpayer's tax liability (i.e., they do not depend on the taxpayer's income), over a three-year period. A total of 20 % of the expenditures for energy-efficiency measures are deductible, up to a maximum funding amount of 40,000 euro per object. Expenditures for an energy consultant are deductible at a rate of 50 %. Refurbishment measures begun after 1 Jan. 2020 are eligible for tax incentives. Another criterion is that the property for which the incentives are being provided has to be more than 10 years old at the time the refurbishment measures are carried out. The incentives are available for insulation measures for walls, roofs and storey ceilings; replacements of windows and external doors; replacements of heating systems; replacement or installation of ventilation systems; installation of digital systems for operational and energy-efficiency optimisation; and optimisations of existing heating systems that are more than two years old. The minimum material requirements pertaining to eligibility of individual measures are set forth in the Ordinance on energy-efficiency-oriented refurbishment measures (ESanMV).

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the tax incentives for refurbishment measures will amount to 1.59 Mt CO2e in 2025.

4.5.5.4 Building Energy Law (GEG) (PaM G.4)

On 18 June 2020, the German Bundestag (lower house of parliament) adopted the Building Energy Law (GEG). On 3 July 2020, the German Bundesrat (upper house of parliament) consented to the law via decision. The GEG then entered into force on 1 November 2020. It provides a new, consistent and coordinated set of regulations for building-energy efficiency and for use of heating energy from renewable energies. In addition, the GEG consolidates the provisions of the Energy Conservation Act (Energieeinsparungsgesetz; EnEG), the Energy Conservation Ordinance (Energieeinsparverordnung; EnEV) (see also the 7th National Communication – PaM 22, 2014 Energy Conservation Ordinance) and the Renewable Energies Heat Act (EEWärmG). Inter alia, the GEG defines the minimum energy-efficiency requirements for new buildings and for existing buildings undergoing comprehensive refurbishments. The requirements apply to both residential and non-residential buildings, subject to the condition that the buildings are regularly heated or cooled. With effect as of 1 Jan. 2023, the requirements for new buildings, with regard to permissible primary energy consumption, have been increased to efficiency standard 55.

Reduction effects

The Building Energy Law (GEG) will bring about a reduction of 3.08 Mt CO2e in the year 2025 (not including effects on the transformation sector).

4.5.6 Transport

4.5.6.1 BEHG pricing for heating and transport (PaM V.1)

The BEHG pricing is described in detail in Chapter 4.5.1.2.

Reduction effects

Pursuant to the 2021 Projections Report, the calculated reduction effects of BEHG pricing in the transport sector will amount to 3.45 Mt CO2e in 2025.

4.5.6.2 EU-CO_2 standards for heavy commercial vehicles (PaM V.2)

In February 2019, the EU adopted CO_2 emissions standards for new heavy commercial vehicles (Parliament and Council of the European Union, 2019). Under the standards, and with respect to a reference value determined in the period July 2019 through June 2020, average CO_2 emissions will decrease by 15 % by 2025 and by 30 % by 2030. The standards provide additional incentives low-emissions trucks (in the form of “super credits” through 2024, and of a benchmark system as of 2025), with non-regulated truck size classes also being taken into account.

The standards apply to heavy commercial vehicles with a total weight of more than 16 tonnes and with 4x2 or 6x2 axle configurations; this group accounts for nearly 80 % of the GHG emissions of trucks (>3.5 t) in Germany (TNO 2018). Also, the standards apply, on a by-manufacturer basis, to the average (fleet average) specific CO_2 emissions (tank-to-wheel), expressed in g CO_2/tkm (Rodriguez 2019).

Reduction effects

In the 2021 Projections Report, the EU CO_2 Standards for heavy duty vehicles are expected to have reduction effects of 2.53 Mt CO2e in 2025.

4.5.6.3 EU CO_2 standards for cars and light commercial vehicles, for 2025 and 2030 (PaM V.3)

In December 2018, a regulation setting binding CO_2-emission targets for new passenger cars and light commercial vehicles for 2025 and 2030 (European Parliament (EP); European Council 2019) was adopted at the EU level. The standards call for the average CO_2 emissions of new passenger cars to decrease by 15 % by 2025 and by 37.5 % by 2030, in each case with respect to the base year 2021. For light duty vehicles, the reductions amount to 15 % (2025) and 31 % (2030). The new EU CO_2 emissions standards follow upon the CO_2 emissions standards for cars (PaM 26) and for light duty vehicles (PaM 27) that were described in the 7th National Communication.

Changes occurring between the 7th and the 8th National Communications

Manufacturers whose zero and low emitting vehicles (ZLEVs) account for a large share of new registrations may decrease their fleet targets by the number of percentage points – up to 5 % – that their fleets lie above the relevant ZLEV benchmark (15 % in 2025 and 35 % in 2030). As of 2021, all new vehicles have to be equipped with an on-board fuel and energy consumption monitoring (OBFCM) device. From 2021 through 2026, and on the basis of the data collected by such devices, the European Commission will monitor the development of discrepancies between test cycles and actual consumption.

Reduction effects

In the 2021 Projections Report, the EU CO_2 emissions standards for cars and light duty vehicles are expected to have reduction effects of 0.98 Mt CO2e in 2025.

4.5.6.4 Development of renewable fuels, and promotion of plants for producing e-fuels / Funding for development of e-fuels and advanced biofuels, and of propulsion technologies for aviation (PaM V.4)

Plants for production of e-fuels from renewable energies are currently in the development and market-preparation phases. Federal funding, provided over the course of several years, can improve the cost-effectiveness assessments for such production plants and support their market launches.

According to current financial planning, 2 billion euro will be available in the KTF/EKF funds, through 2024, for promotion of the development of renewable fuels; of plants for production of e-fuels; of advanced biofuels; and of propulsion technologies for aviation. That figure includes 0.8 billion euros from the National Hydrogen Strategy.

Reduction effects

The 2021 Projections Report forecasts that this package of measures will yield GHG reductions of 0.79 Mt CO2e in 2025.

4.5.6.5 Reduction of the EEG levy as of 2021 (PaM V.5)

Economic instruments and financial support

The EEG levy is among the cross-cutting instruments that have to be assessed in terms of their cross-cutting effects. In the present report, the reduction of the EEG levy is taken into account in keeping with the description provided in section 3 (transport sector).

Reduction effects

The 2021 Projections Report forecasts that reduction of the EEG levy will yield GHG reductions of 0.74 Mt CO2e in 2025.

4.5.6.6 Promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems (PaM V.6)

In the period July 2018 through March 2021, the funding programme “Energy-efficient and/or low-carbon heavy commercial vehicles” (“Energieeffiziente und/oder CO_2-arme schwere Nutzfahrzeuge” – EEN) provided options for funding of heavy commercial vehicles with alternative drive systems. It included CNG heavy commercial vehicles (8,000 euro), LNG heavy commercial vehicles (12,000 euro, through the end of 2020) and battery-only and fuel-cell vehicles (40,000 euro for heavy commercial vehicles of at least 12 tonnes; 12,000 euro for smaller heavy commercial vehicles). With a funding volume of about 32 million euro, the EEN funding programme supported procurement of 2,543 LNG trucks, 311 CNG trucks and 13 electric trucks (Federal Ministry for Digital and Transport (BMDV), 26 Oct. 2022).

In 2020, the Federal Ministry for Digital and Transport presented a global concept for climate-friendly commercial vehicles as a central outline for implementation of the projects of the Climate Action Programme 2030. One of the three core measures involved calls for funding procurement of commercial vehicles with alternative, climate-friendly drive systems. Such funding can be provided on the basis of the guideline on promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems, along with the relevant

fuelling and charging infrastructure (KsNI). Germany's 2022 budgetary plan – which covers a period after the period reported on here – includes a total of about 1.3 billion euro, from the EKF/KTF funds, for the procurement of climate-friendly commercial vehicles. This figure includes an additional 0.2 billion euro that, as a result of the coalition committee's meeting of 3 June 2020, are earmarked for federal investments in a "Bus and Truck Fleet Modernisation Programme." Also, for implementation of measure 6 of the National Hydrogen Strategy, 0.1 billion euro are earmarked for relevant market activation and for support of investments in hydrogen-powered vehicles.

Also as a result of the coalition committee's meeting of 3 June 2020, a temporary fleet-replacement programme for craftsmen and SMEs, focussing on electric commercial cars up to 7.5 t, is to be carried out in the near term. The programme, which was approved in the framework of the funding guideline on electromobility of 5 December 2017, extends to electric vehicles in classes N1, N2 and N3. For it, the Federal Ministry for Digital and Transport (BMDV) is providing funding of 50 million euro, to be disbursed on a first-come, first-served basis. In each case, the funding is provided in the form of an investment subsidy, and it covers 40 % of the additional investment costs incurred. Also, bonuses of 10 % or 20 % are available for small and medium-sized enterprises (SMEs) that would otherwise be unable to carry out such projects.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems will amount to 0.63 Mt CO2e in 2025.

4.5.6.7 Strengthening of rail freight services: Funding of railway lines and systems; federal programme for the future of rail freight services (Bundesprogramm Zukunft Schienengüterverkehr); network expansion; capacity increases; follow-up funding (PaM V.7)

The "Price support for freight traffic" ("Trassenpreisförderung im Güterverkehr" – TraFöG) programme promotes rail freight services by sharing in the costs for track access. The legal framework for the funding measure consists of a guideline, published by the Federal Ministry of Transport and Digital Infrastructure (BMVI) on 12 December 2018, on promotion of rail freight services via shared financing of approved track access charges (af-TP) of 10 December 2018. The federal budgets from 2019 through 2022 include 350 million euro annually for this purpose. In 2023, 175 million euro have been earmarked for it. The average funding rate for 2020/21 is about 50 %. This effort is to be complemented by a funding programme for shared financing of service systems for rail freight services, with an emphasis on single-wagonload freight, that will be launched at the beginning of the 2020/2021 working timetable period. For this programme, annual allocations of 80 million euro (as of financial year 2021) and 40 million euro (as of financial year 2022) are planned. Projects in the areas of digitalisation, automation and innovative vehicle engineering technology are also being funded via the federal programme for the future of rail freight services (Bundesprogramm Zukunft Schienengüterverkehr). The pertinent funding guideline has been in force since 20 May 2020. For such projects, the federal budgets as of 2020 include annual allocations of 30 million euro. Still other funding measures for strengthening rail freight services are being carried out. In particular, these include an effort to increase the rail network's capacity, to make higher load factors possible – and thereby reduce costs in the rail freight services sector (740 meter network programme; electrification); promotion of combined transports; and planned, updated funding of rail connections and other systems required in

rail freight services (in particular, replacement tracks, feeder tracks, and reserved tracks for industry, and multifunctional facilities for road/rail freight handling/transfer).

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the Strengthening of rail freight services programme will amount to 0.33 Mt CO2e in 2025.

4.5.6.8 Increase of public transport + regionalization funds, improvement of service quality of public transport (PaM V.8)

This measure is part of the Climate Action Programme 2030 (measures package 3.4.3.2). In complements the programme for strengthening local public rail transport (Stärkung Schienenpersonennahverkehr) and the programme for improving services and attractiveness of local public transportation (Strengthening public transport – PaM 30) of the 7th National Communication. In 2019, federal funding totalling about 333 million euro per year was available, pursuant to the Local Transport Financing Act (Gemeindeverkehrsfinanzierungsgesetz – GVFG), for expansions and improvement of local public transportation. The Third Act for Amendment of the Local Transport Financing Act of 6 March 2020[119] made funding of about 665 million euro available for the year 2020. As of 2021, the funding has increased to 1 billion euro per year, and as of 2025 it will increase to 2 billion euro per year. Further increases of 1.8 % p.a. will take place as of 2026. The increase to 1 billion euro was agreed in the coalition agreement of 2018.

In addition, regionalisation funding pursuant to the Fifth Act for Amendment of the Regionalisation Act (Fünftes Gesetz zur Änderung des Regionalisierungsgesetzes)[120] was increased by 150 million euro in 2020. Taking account of funding dynamization, the additional available funding will reach 303 million euro in 2021, about 308 million euro in 2022 and about 464 million euro in 2023. As of 2024, the existing dynamization rate of 1.8 % will apply. As a result, the Länder will receive additional regionalisation funding totalling 5.25 billion euro in the period 2020 through 2031.

In 2020, via the Act on supporting measures for implementation of the economic and crisis-management package (Gesetz über begleitende Maßnahmen zur Umsetzung des Konjunktur- und Krisenbewältigungspakets) of 14 July 2020, the Länder received a one-time regionalisation-funding increase of 2.5 billion euro, as financing support for local public transport – to offset the sharp reductions in fare revenue incurred during the coronavirus pandemic. For the year 2021, the additional funding provided to offset pandemic-related financial burdens amounted to 1 billion euro. For 2022, 1.2 billion euro was provided.

Plans call for additional funding programmes to enhance the attractiveness of public passenger transport. Such efforts are to include federally supported model projects for strengthening local public transportation. On 21 Jan. 2021, for implementation of this measure, the Federal Ministry for Digital and Transport (BMDV) published the funding guideline “Model projects for strengthening local public transport” (“Modellprojekte zur Stärkung des ÖPNV”). For these funding activities, and for the period 2021-2024 (1st funding call), budgetary resources totalling about 200 million euro are available; for the period 2022-2025 (2nd funding call), budgetary resources totalling about 150 million euro are available.

[119] Drittes Gesetz zur Änderung des Gemeindeverkehrsfinanzierungsgesetzes vom 06.03.2020, German Federal Law Gazette (Bundesgesetzblatt No 11 of 12 March 2020, p. 442).
[120] Fünftes Gesetz zur Änderung des Regionalisierungsgesetzes vom 06.03.2020, German Federal Law Gazette (Bundesgesetzblatt No 11 of 12 March 2020, p. 445).

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of this instrument will amount to 0.21 Mt CO2e in 2025.

4.5.6.9 International aviation and maritime transport (PaM V.9)

The parties to the Kyoto Protocol have agreed to shift efforts to limit or reduce emissions from aviation and maritime transport into the competent specialised UN agencies – the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO). To this end, various developments have taken place in the two organisations, developments which Germany has supported.

International maritime transport

Within the IMO, Germany, represented by the Federal Ministry for Digital and Transport (BMDV), is among the key initiators of efforts to develop rules for GHG-emissions reduction and air quality control. In April 2018, the IMO approved a kick-off strategy for reduction of GHG emissions from international maritime transport and, by defining ambitious sector-specific targets, ushered in the end of the fossil-fuel era in this sector. After carrying out intensive preliminary work, the IMO Marine Environment Protection Committee (MEPC) has agree to define an emissions reduction pathway for the period until 2050. The pathway calls for a reduction of at least 50% with respect to 2008, and – ideally – even for complete decarbonisation by 2100.

The kick-off strategy now provides a basis for the future development of internationally binding measures to reduce GHG emissions in maritime transport. The current emphasis of efforts in this area is on development of viable, results-oriented measures for implementation of the strategy. Also, a focus is now being placed on “short-term measures.” Such measures, which are to be in force by 2023, are to be aimed at increasing ships’ technical and operational efficiency by 40% by the year 2030, and at preventing any further GHG emissions increase in maritime transport (“*peak as soon as possible”*).

In cooperation with Denmark and France, Germany has developed a proposal for short-term energy efficiency measures. It builds on the existing management plan for operational measures, and it provides incentives for the development and integration of improved ship designs, technological innovations and efficient procedures for ship operations. In sum, it comprises both technical and operational measures. At its 75th meeting, in November 2020, the Marine Environment Protection Committee (MEPC) is expected to carry out final deliberations regarding the proposals.

International aviation

The International Civil Aviation Organization (ICAO) addresses technical aspects of environmental issues in the framework of its Committee on Aviation Environmental Protection (CAEP), to which various working groups report. In the past, the ICAO has also addressed GHG issues by establishing various working groups (some with high-ranking members) charged with illuminating central political questions relative to the introduction of climate protection instruments.

In January 2012, the aviation sector was integrated within the EU Emissions Trading System, in keeping with EU Directive 2008/101/EC. Application of the EU-ETS to flights outside of the EEA was temporarily suspended, and these exemptions were extended when the 38th ICAO assembly agreed to develop a Carbon Offsetting and Reduction Scheme (CORSIA) for the international aviation sector.

At the 39th ICAO assembly, held in 2016, the organisation's Member States agreed on a global, market-based measure for stabilising CO_2emissions from international aviation at the level they had in the year 2020. As of 2021, airlines will offset CO_2 emissions over and above the level of the year 2020 by purchasing carbon credits from projects for reduction of CO_2 emissions. For implementation of CORSIA, a working group within the ICAO's Committee on Aviation Environmental Protection (CAEP) has developed "Standards and Recommended Practices" (SARPs), along with other elements of the applicable rules. In 2018, the ICAO Council adopted the CORSIA-SARPs. CORSIA reporting obligations began on 1 Jan. 2019. Further implementation of CORSIA is divided into three phases – a voluntary pilot phase (2021–2023), a voluntary first phase (2024–2026) and a compulsory second phase – in keeping with certain criteria oriented to the activity levels of international flights (2027–2035).

As an ICAO member, Germany has expressed its support for a measure that is environmentally effective, neutral with respect to competition and permanently robust. Germany has complemented its political support with concrete technical collaboration in the ICAO CAEP's relevant working groups.

Within the EU, CORSIA is to be implemented via the Emissions Trading Directive (ETD), 2003/87/EC. In the framework of the European Green Deal, plans call for reducing free issuance of certificates to airlines and for intensifying efforts to shift passenger transports from air travel to rail travel.

Reduction effects

Because the measure is affected by emission sources outside of Germany, it was not modelled in the 2021 Projections Report.

4.5.7 Waste management sector, and other areas

The key climate-relevant regulatory framework conditions for the waste management sector, within the period since 1993, have included the Technical Instructions on Municipal Waste (TA Siedlungsabfall; TaSi), which in 2001 was followed by the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (AbfAblV) and in 2009 by the Landfill Ordinance (Deponieverordnung); the provisions of the Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible Waste Disposal (KrW-/AbfG) of 1996 and, as of 2012, of the Circular Economy Act (KrWG); the provisions of the Commercial Wastes Ordinance (Gewerbeabfallverordnung); and the provisions of the Ordinance on Packaging (Verpackungsverordnung), which followed the Packaging Act of 2017.

4.5.7.1 Funding of landfill aeration, and funding of technologies for optimised gas collection in municipal waste (PaM W.1)

The instrument "landfill aeration" (also referred to as "aerobic in-situ stabilisation of municipal waste landfills) was described in detail in the 7th National Communication (PaM 37). Since 2013, landfill aeration has been funded with funding from the National Climate Protection Initiative. Technologies for optimised gas collection in municipal waste are funded by the same initiative. Their importance for the waste management sector is similar to that of landfill aeration. For this reason, the two instruments are described here in combination.

Changes occurring between the 7th and the 8th National Communications

The Climate Action Programme 2020 expanded this funding and extended the relevant application periods until 2018. As a result of the continuation and intensification of this measure, as described in the Climate Action Programme 2020 – and especially of intensified efforts to inform and motivate stakeholders, and of an increase of the maximum available grant level, a total of 43 submitted projects were approved by October 2018. On 1 Jan. 2019, the new municipal guideline entered into force. On 22 July 2020, an amendment introduced slight changes to it. By 31 March 2021, an additional 32 projects were launched, all of which are to be completed by September 2022. Applications may be submitted until 31 Dec. 2022. Funding is normally provided for 18 months. The final aeration measures within the programme are to be approved in 2025 and then begin in 2027. Thereafter, regulatory measures pursuant to the 2030 measures programme may enter into force.

In the framework of the municipal guideline, optimised gas collection in landfills is now being funded. This is expected to improve existing gas collection by at least 25 %, or ensure that at least 60 % of the gas produced is collected.

Reduction effects

In the Projection Report, the reduction effects of the funding programme for landfill aeration and for technologies for optimised gas collection are quantified together; they amount to 0.37 Mt CO2e in 2025.

4.5.7.2 Avoidance of food waste (PaM W.5)

In the Climate Action Programme 2030, the effort to reduce and avoid food waste is referred to as a cross-cutting measure. In Feb. 2019, the federal government adopted a National Strategy for Food Waste Reduction, aimed at cutting food waste in half by 2030. While the GHG-reduction effects of this measure are difficult to quantify in other sectors, it does have a direct effect on emissions in the waste management sector.

Reduction effects

According to estimates of the 2021 Projections Report, the reduction effects of the measure for avoidance of food waste will amount to 0.07 Mt CO2e in 2025.

4.5.8 Agriculture

4.5.8.1 The EU’s Common Agricultural Policy (CAP) (PaM A.1)

The economic and legal framework for the agriculture sector is shaped primarily by market trends, the EU’s Common Agricultural Policy (CAP) and national regulatory law. It is also affected by decisions on resources and energy policy. Such decisions determine the extent to which agricultural crops and residual materials are used for substance and energy recovery. Such use, in turn, has concrete impacts on land use and on emissions in this sector. The CAP was described in detail in the 7th National Communication.

The proposals presented by the European Commission in May 2018, for the post-2020 CAP, call for a transition from greening and cross-compliance requirements into a new “conditionality.” Since no final decisions have yet been made in this regard, the concrete impacts of the next CAP reform, which will enter into force in 2023, cannot yet be taken into account. In the second pillar of the CAP, and in the current grant period, existing environmental measures in the agricultural sector are being continued as “agri-environment-climate measures” (AECMs), and organic farming is being promoted via a separate measure. In the present context, support measures within the EU CAP’s second pillar have been updated

on the basis of the assumption that the financial framework and programme planning for the period 2014 through 2020 can simply be projected forward beyond the year 2020, since at the time the report was being prepared no detailed information about the further design of the 2nd pillar was yet available.

Reduction effects

The effects of CAP provisions on GHG emissions in Germany are not modelled in the 2021 Projections Report. CAP implementation is reflected in some individual instruments (such as measures to protect permanent grassland).

4.5.8.2 Increase of share of cattle and pig slurry which is stored in gas-tight tanks to 70% (PaM A.2)

The Climate Action Programme 2030 calls for increasing the share of cattle and pig slurry which is stored in gas-tight tanks to 70%. This is to be achieved by promoting digestion of animal-based farm manure and of agricultural crop residues, as well as by a range of additional measures. The plans in this area call for a mix of funding measures and updated regulatory provisions. For example, a new funding system for new biogas plants is expected to support expansion of manure digestion in biogas plants (cf. the 7th National Communication; PaM 41). For existing systems, options for follow-on uses are to be offered. Also, gas-tight systems for storage of digestates are to be funded, and obstacles hindering use of manure digestion eliminated. The funding in this context continues to be provided via the Renewable Energy Sources Act (EEG). In addition, funding from the Energy and Climate Fund (EKF/KTF), amounting to 60 million euro annually, is planned (initially, for the period 2021 until 2023). If necessary, these measures can be improved in the framework of the Federal Climate Change Act's review mechanism. Also, relevant implementation is to be supported via regulatory provisions for gas-tight storage of digestates in existing and net biogas plants, in connection with a transition period for funding. For large animal-husbandry facilities, regulatory requirements for gas-tight manure storage are to be introduced.

Reduction effects

In the 2021 Projections Report, the reduction effects from an increase in the share of cattle and pig slurry which is stored in gas-tight tanks are estimated as 1.581 Mt CO2e in 2025.

4.5.8.3 Amendment of the German Fertiliser Ordinance (PaM A.3)

The amendment of the of May 2017 was described in detail in the 7th National Communication.

Changes occurring between the 7th and the 8th National Communications

The German Fertiliser Ordinance (DüV) was amended in April 2020. The amended DüV 2020 contains, inter alia, new, tighter requirements in the areas of fertilisation planning; waiting periods for spreading of fertilisers in the fall and winter; minimum distances to above-ground waters; fertilisation on inclined areas; and strict requirements for areas with nitrate contamination, such as 20 % reductions of nitrogen fertilisation. These measures are expected to promote more-efficient, more resource-saving use of nitrogen – and, thus, decreases in nitrogen surpluses. Such effects will also entail reductions of nitrous oxide emissions from fertilisation.

Reduction effects

In the 2021 Projections Report, this measure is expected to have reduction effects of 1.1 Mt CO2e in 2025.

4.5.8.4 Reduction of use of peat as substrate in gardening (PaM A.4)

The Climate Action Programme 2030 cites “Reduction of use of peat as substrate in gardening” as a measure in its Chapter 3.4.7.3. The measure provides for intensification of trials and research on substitute materials; establishment of advising services for commercial operations; provision of information to the public regarding alternatives to peaty potting soils; and provision of training for special user groups. Substitutes for peat are now available for production of potting soils, and peat use can be reduced in substrates for commercial horticulture. Additional R&D are still required before completely peat-free alternatives for commercial growers can be produced, however. Sales of peaty potting soils are to be phased out in the consumer sector by 2026, and peat use is to be reduced by 70 % in the commercial horticulture sector by 2030. According to current expectations, peat extraction will be discontinued in Germany by 2040, and the relevant land areas will then be rewetted.

Reduction effects

In the 2021 Projections Report, this measure is expected to have reduction effects of 0.909 Mt CO2e in 2025.

4.5.8.5 Expansion of organic farming (PaM A.5)

In its new version of 2017, the German Sustainability Strategy calls for expanding the proportion of agricultural land farmed organically to 20% of all agriculturally utilised land. This measure is described in the 7th National Communication (PaM 40).

Changes occurring between the 7th and the 8th National Communications

As noted in Chapter 3.4.5.3 of the Climate Action Programme 2030, “Expansion of organic farming” (“Ausbau des Ökolandbaus”), laws are being updated to reflect preference for practices such as organic farming that are especially environmentally friendly, and the financial support for such practices is being optimised; the necessary funding is being secured and expanded. Implementation of the country’s Strategy for the Future of Organic Farming (Zukunftsstrategie Ökologischer Landbau) is providing additional impetus for growth throughout the entire value chain in this area, and consolidating and enhancing funding for research into organic farming. The aim of the German Sustainability Strategy (federal government, 2016) is for the proportion of organically farmed agricultural land to increase to 20 % of the total agricultural land area. If the accelerated growth of organic farming seen in the period 2015 through 2019 continues, the proportion of organically farmed agricultural land would increase to between 17 and 18 % in 2030. With the help of intensified funding, the proportion is expected to grow from 9.7 % in 2019 to 20 % in 2030. Because organic farming does not use mineral nitrogen fertilisers, the key benefits of expanding the organically farmed area include reductions of nitrogen inputs into agricultural soils and nitrous oxide emissions from agricultural soils.

Reduction effects

The 2021 Projections Report quantifies the GHG-reduction effect at 0.37 Mt CO2e in 2025, subject to the condition that the year-2020 expansion target for organic farming is met. For comparison, we present a scenario in which the organically farmed area increases to a share of 17 % by 2030.

4.5.8.6 NEC Directive (PaM A.6)

The provisions of the new NEC Directive (EU) 2016/2284 on the reduction of national emissions of certain atmospheric pollutants, which was adopted in December 2016, include requirements for reduction of NH_3 emissions by 29 % by 2030, with respect to their level in 2005. This instrument is described in detail in the 7th National Communication.

Changes occurring between the 7th and the 8th National Communications

The Climate Action Programme 2030 (Chapter 3.4.5.1) calls for rapid, comprehensive implementation of all reduction options provided by the measures of the National Air Pollution Control Programme (NLRP; federal government, 2019), to achieve conformance with the NEC Directive. Reductions of NH_3 emissions also reduce indirect nitrous oxide emissions from nitrogen deposition caused by agriculture. Such reductions can be achieved via systematic implementation of various measures for preventing and reducing NH_3 emissions from agriculture, including covering of slurry-storage facilities; immediate incorporation or injection of manure into the soil; use of urease inhibitors in connection with use of mineral urea fertilisers; and intensified use of exhaust-air filters in swine and poultry farming. Many of these measures are already required by law – either by the current Fertiliser Ordinance (Düngeverordnung 2020; low-emissions spreading of animal manures, use of urease inhibitors) or by immission-control law (durable, tightly sealing covers for slurry and digestate storage facilities in installations subject to licensing; Länder decrees on purification of exhaust air from large pig-fattening operations). Also, procurement of certain types of emissions-reducing machines and equipment is being promoted, via investment subsidies.

Reduction effects

The 2021 Projections Report puts the NEC Directive's reduction effects at 0.35 Mt CO2e in 2025, under the assumption that the Directive is transposed in keeping with the measures of the National Air Pollution Control Programme.

4.5.8.7 Promotion of Energy Efficiency and CO_2 Savings in Agriculture and Horticulture (PaM A.7)

The Guideline on Promotion of Energy Efficiency and CO_2 Savings in Agriculture and Horticulture, which has been in place since 2016, provides an important range of instruments for promoting energy efficiency and renewables-based fuel substitutions in agricultural and horticultural operations. The programme is promoting advising; investments in suitable individual measures; and investments for modernisation and construction/procurement of buildings, equipment and machines. At the same time, it permits funding recipients to take advantage of other funding options that are also available to other sectors, including funding programmes, such as the Renewable Energy Sources Act (EEG); the Market Incentive Programme for expansion of renewable energies; and the KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations. In addition, CO_2 pricing of fossil fuels in the heating and transport sectors (BEHG) also affects agricultural energy consumption, and thereby supports measures under this guideline.

Reduction effects

Pursuant to the 2021 Projections Report, the reduction effects of the Guideline on Promotion of Energy Efficiency and CO_2 Savings in Agriculture and Horticulture will amount to 0.5 Mt CO2e in 2025. In calculation of emissions reductions, both energy-efficiency increases and renewables-based fuel substitutions are taken into account. All of the emissions reductions are allocated to the Guideline on Promotion of Energy Efficiency and CO_2 Savings in

Agriculture and Horticulture, since they are difficult to break down in accordance with the other relevant measures.

4.5.9 Land Use, Land Use Change and Forestry (LULUCF)

4.5.9.1 Reduced land use for urban development and transport (PaM F.1)

The German Sustainability Strategy calls for reducing land use for urban development and transport to less than 30 ha per day, by 2030. The goal is to be achieved via sustainable land management. This measure is described in the 7th National Communication (PaM 44).

Changes occurring between the 7th and the 8th National Communications

The Integrated Environmental Programme 2030 calls for reducing land use to no more than 20 ha/day by 2030. The German Sustainability Strategy (the new version of 2021) envisions the attainment of a circular land-use economy by 2050 (with zero net land use).

Reduction effects

The 2021 Projections Report calculates that reducing land use for urban development and transport would reduce emissions by 1.17 Mt CO2e in 2025, if the target of 30 ha of land use per day is achieved.

4.5.9.2 Conservation of grassland (PaM F.2)

Grassland conservation is one of the measures included in the Climate Action Programme 2020. It was described in the 7th National Communication (PaM 45). The manner in which grassland conservation, in the framework of the CAP greening measures, is being carried in Germany is that farms that receive direct CAP payments, and that are subject to greening regulations, cannot plough or convert permanent grassland without first obtaining official authorisation. In cases in which the land to be ploughed or converted is permanent grassland that existed as such prior to 1 Jan. 2015, they must also demonstrate the availability of a substitute land area, of equal size, which then must be converted to new permanent grassland. A number of German Länder also have provisions in place for quantitative conservation of permanent grassland.

Changes occurring between the 7th and the 8th National Communications

In its Chapter 3.4.7.2, the Climate Action Programme 2030 calls for permanent grassland to be protected. As land-use statistics now show, the decline in Germany's permanent grassland area has been stopped. In the climate action programme's new, post-2020 funding period, permanent-grassland conservation is to be continued in an effective way in the "conditionality" framework, in the form of environmental requirements applying to all land- and animal-oriented measures within the first and second pillars of the EU CAP. In addition, this will be supported via targeted funding, within the framework of the second pillar of the CAP, for conservation of extensively managed permanent grassland. Furthermore, the Federal Ministry of Food and Agriculture (BMEL) is planning to prepare a grassland strategy that will identify specific areas of activity for protecting grassland and reinforcing sustainable grassland use.

Reduction effects

In the 2021 Projections Report, efforts to protect permanent grassland are expected to have reduction effects of 0.64 Mt CO2e in 2025.

4.5.10 Assessment of individual measures, by sectors

Table 8 shows all of the individual measures that are quantified in the 2021 Projections Report. Here, some of the policies and measures described in Chapter 4.5.1 as cross-cutting efforts have been separately quantified for the relevant individual sectors (for example, EU ETS, BEHG pricing). In addition, Table 8 presents all quantified instruments and measures that have been updated or newly introduced since the last Biennial Report.

For a range of measures, the reduction effects have not been estimated, for various reasons. For some measures, for example, the empirical data needed to support estimation of reduction effects are lacking. In individual cases, measures have been quantified in combination with other measures, as groups. The individual-measure assessments shown in Table 8 for the years 2020 and 2021 are not included in the 2021 Projections Report. In hindsight, it seems clear that these modelled emissions data are of limited reliability, since actual developments diverged from what had been expected (e.g. ETS and gas prices, impacts of the coronavirus pandemic, a poor wind year). In some cases, no assessments were carried out for the 2020 and/or 2021, because the measures involved had not yet taken effect. The following section describes the sector-specific approach used in assessing individual measures.

Energy industry

The individual measures in the electricity sector are assessed, in each case, by comparing them with a model run without the measure. To this end, the pertinent measure is deactivated by varying its input data within the model for its effectiveness period. The measure's reduction effects are then quantified by comparing a) the CO_2 emissions from a model run in which the measure is deactivated and b) the CO_2 emissions in a model run with the measure. The projection report does not calculate a complete without-measures scenario for the electricity sector, because it is difficult to determine how the structure of Germany's electricity generation sector would have developed without the influence of already long-acting instruments such as the Renewable Energy Sources Act (EEG) or the EU-ETS.

Buildings: heating and cooling

Most of the individual measures are assessed on a bottom-up basis. One exception is the BEHG (CO_2 pricing of fossil fuels), for which the effects have been estimated via INVERT/EE-Lab, with the help of models. A description of the assumptions on which the individual measures are based is provided in the 2021 Projections Report (Chapter 7.2.3). The effects of the individual measures are estimated by comparing with-measures scenarios with without-measures scenarios. In each without-measures scenario, it is assumed that the relevant individual measure does not exist and thus cannot have any effect. For the period as of 2020, the individual measures' effects are estimated, with the result that the cumulative annual savings, in each case, apply to the period between 2020 and the relevant year under consideration. Even if a measure already existed prior to 2020 (such as funding for new construction and for renovation), its effects are quantified only for the period beginning in 2020.[121]

Transport

The reduction effects are assessed by comparing with-measures scenarios with without-measures scenarios. The reference year for the assessments is 2020, meaning that the

[121] Table 63 in the 2021 Projections Report presents an overview of the individual measures that have been assessed, along with the assumptions made for the without-measures scenarios used for comparison.

measures are assumed to have been identically designed prior to 2020, and that the individual measures yield reduction effects by 2020 at the earliest.[122]

Waste management sector, and other areas

The reduction effects are assessed by comparing with-measures scenarios with without-measures scenarios. The without-measures scenario includes the emissions trends for landfill storage of waste, as subject to the Landfill Ordinance (Deponieverordnung), but it does not include the emissions reductions resulting from landfill aeration and optimised gas collection. In addition, the without-measures scenario includes the effects of greater biowaste production as a result of the Closed Substance Cycle Waste Management Act (Kreislaufwirtschaftsgesetz), but it does not take account of reductions of food waste. Consequently, the reductions are estimated for both a) the measures for landfill aeration and optimised gas collection and b) the measures for reduction of food waste. Overall, the aforementioned measures can achieve reduction effects of 1.2 Mt CO2e by the year 2040. Some 90 % of the reductions are achieved via the measures for landfill aeration and optimised gas collection. The potential savings from food-waste reduction, in the waste management sector, amount to about 0.1 Mt CO2e. The GHG reductions occur in that less waste requiring treatment is produced. Overall, avoidance of food waste can even lead to much greater emissions reductions if it reduces the demand for food production, transport and storage.[123]

Agriculture

The measures all have impacts on N_2O emissions, which are influenced by fertilisation. For this reason, the measures interact with their overlapping effects. For impacts assessment, the measures were implemented successively, in the order given, in the GAS-EM calculation programme. As each measure was added, its resulting additional effect was determined. Because of the interactions involved, the individual measures' effects, as given, depend on the way in which the measures are combined, as well as on the sequence in which their effects are calculated. As a result, the results can vary when different combinations and sequences are used. The effects of the individual measures are estimated by comparing with-measures scenarios with without-measures scenarios. In each without-measures scenario, it is assumed that the relevant individual measure does not exist and thus cannot have any effect. The assessments of the individual measures for 2020 are based on either a) an expert's comparison with the situation applying in 2018 or b) an assumed situation without the relevant measure, as determined on the basis of the calculations of the 2021 Projections Report and the available data for 2020. [124]

LULUCF

The effects of the individual measures are estimated by comparing with-measures scenarios with without-measures scenarios. In each without-measures scenario, it is assumed that the relevant individual measure does not exist and thus cannot have any effect. The effects of the individual measures were determined by successively introducing the (with-

[122] Table 92 in the 2021 Projections Report presents the measures; in each case, the measure's design in the with-measures scenario; and the assumptions made regarding the measure's design in the comparative scenario without the measure (without-measures scenario).
[123] Table 114 in the 2021 Projections Report presents the assumptions made, for the assessed individual measures, in the without-measures scenario.
[124] Table 99 in the 2021 Projections Report presents the assumptions made, for the assessed individual measures, in the without-measures scenario.

measures-scenario) measures into the calculations. The measures' effects include follow-on effects from land-use changes resulting [from] […] interactions.[125]

[125] Table 114 in the 2021 Projection Report presents the assumptions made, for the assessed individual measures, in the without-measures scenario.

Table 8: Overview of policies and measures through August 2020

Name of mitigation action	GHG (s) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative) (kt CO_2 eq)		
								2020	2021	2025
Energy industry										
Act on the Phase-Out of Coal Plants (PaM E.2)	CO_2	Reduction of capacities of coal-fired power plants to zero by the end of 2038; partial replacement of coal CHP plants with natural gas CHP plants	Economic, Regulatory	Implemented	Gradual shut-down of all coal-fired power plants until 2038; partial replacement of coal CHP plants with natural gas CHP plants	2020	Federal Government	54,000	114,000	116,000
Renewable Energy Sources Act (PaM E.1)	CO_2	Increase of renewable energy capacities (wind onshore 71 GW in 2030, wind offshore 20 GW in 2030, solar PV 100 GW in 2030, biomass 8,4 GW in 2030) to reach 65% renewable energy in gross electricity consumption in 2030	Economic; Regulatory	Implemented	Funding rates (based on feed in tariff or auctions) to increase the generation of renewable electricity	2000	Federal Government	NE	NE	33,000
EU Emissions Trading Scheme (ETS) in energy sector (PaM I.1)	CO_2	Reduction of GHG emissions in regulated sectors according to the certificate budget	Economic	Implemented	EU Emissions Trading scheme with increasing prices for EUAs, effect in the electricity sector.	2005	Federal Government	NA	NA	8,200
Promotion of innovative district heating network measures (PaM E.3)	CO_2	no explicit quantified objective	Economic; Regulatory	Implemented	Bundle of promotion measures for innovation in district heating networks (solar thermal heat, heat pumps, waste heat, heat losses)	2017	Federal Government	NE	NE	570
EU Emissions Trading Scheme (ETS) in industry sector (PaM I.1)	CO_2; N_2O	Reduction of GHG emissions in regulated sectors according to the certificate budget within the EU Emissions Trading System (EU ETS)	Economic	Implemented	Emissions Trading Scheme (effect in the industry sector)	2008	Federal Government	0	1,036	3,482
Energy advice for SMEs (PaM I.7)	CO_2	Contribution to energy savings target under Art. 7 EED (Directive 2912/27/EU; amending Directive 2018/2002). Contribution to energy efficiency target under Art. 3 EED and national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Economic; Information	Implemented	Opportunity for SMEs to get cheaper energy audits and grants for investments in energy saving measures	2008	Federal Government	1,598	1,416	814
Federal support for energy efficiency in the economy – grants and loans (PaM I.4)	CO_2	Contribution to sectoral GHG reduction target for industry until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 140 / 118 Mt CO2eq. in 2030)	Fiscal	Implemented	Financial support for investment in energy efficiency and climate protection technologies by grants and loans	2019	Federal Government	1,266	1,850	3,764
Energy efficiency and climate protection networks (PaM I.5)	CO_2	Contribution to energy savings target under Art. 7 EED (Directive 2912/27/EU; amending Directive 2018/2002). Contribution to energy efficiency target under Art. 3 EED and national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Voluntary/negotiated agreements; Information; Fiscal	Implemented	Establishment and support of company networks aiming at energy efficiency and GHG reduction	2014	Federal Government	1,659	1,930	2,416
Federal support for energy efficiency in the economy – support for competition (PaM I.4)	CO_2	Contribution to sectoral GHG reduction target for industry until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 140 / 118 Mt CO2eq. in 2030)	Economic	Implemented	Financial support for investment in energy efficiency and climate protection technologies by a tendering model	2019	Federal Ministry for Economic Affairs and Energy	0	64	276
Energy audit for non-SMEs (PaM I.6)	CO_2	Contribution to national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Regulatory	Implemented	Mandatory audits for non-SMEs (implementation of Art. 8 EED)	2015	Federal Government	1,189	1,345	1,831
KfW Efficiency Programme: Soft loans (PaM I.8)	CO_2	Contribution to national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Fiscal	Implemented	Soft loan program of the KfW to support investments in energy efficiency measures	2012	Federal Government	1,167	1,332	1,782
Energy management and tax discount for industry (energy tax)	CO_2	Contribution to energy savings target under Art. 7 EED (Directive 2912/27/EU; amending Directive 2018/2002). Contribution to energy efficiency target under Art. 3 EED and national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Economic	Implemented	Discounts on energy tax are bound to the implementation of energy management and a commitment on energy saving	2010	Federal Government	3,423	3,318	2,875
Energy management and discount for industry (Renewable Energy Levy)	CO_2	Contribution to energy savings target under Art. 7 EED (Directive 2912/27/EU; amending Directive 2018/2002). Contribution to energy efficiency target under Art. 3 EED and national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Fiscal	Implemented	Discount for industry on the Renewable Energy Levy when introducing energy management systems	2008	Federal Government			
Industry										
Revision of the Road Traffic Licensing Regulation to limit HFCs in passenger	HFCs	No quantified objective for PFCs under the EU-ETS	Regulatory	Implemented	The German Road Traffic Licensing Regulation (Straßenverkehrszulassungsordnung) had been revised in order to transpose into national law the limitation of HFC in passenger	2007	Federal Government	NE	NE	4,662

Name of mitigation action	GHG (s) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative) (kt CO_2 eq)		
								2020	2021	2025
cars' air conditioning system (PaM I.10)					cars' air conditioning systems set out in the EU MAC-Directive (2006/40/EC)					
HFC-Phase-Down according to EU F-Gas-Regulation (PaM I.11)	HFCs	Objective on EU level: 70 % emission reduction for F-gases by 2030 compared to 2005	Economic; Regulatory	Implemented	The EU F-Gas Regulation 517/2014 features a phase-down scheme for the placing on the market (POM) of HFCs. In the quantification of effects, the effects of supplementing measures on National level are included: HFC leakage prevention due to Requirements concerning F-gas leakage beyond the levels of the F-gas Regulation (517/2014), as implemented in Chemicals Climate Protection Ordinance (Chemikalien-Klimaschutzverordnung) as well as Federal Support Scheme for commercial air conditioning and cooling Systems' under the "National Climate Initiative' (Investment subsidy for highly efficient & low-HFC air-conditioning & refrigerating devices in commercial applications)	2015	Federal Government	NA	NA	3,455
SF_6 bans under the EU F-Gas Regulation (PaM I.12)	SF_6	Objective on EU level: 70 % emission reduction for F-gases by 2030 compared to 2005	Regulatory	Implemented	Specific bans on the use of SF6 under Art 13 of the EU F-Gas Regulation 517/2014, and specific prohibitions under Art 11 / Annex III of Regulation 517/2014 to place SF_6-containing products on the EU market.	2006	Federal Government	NA	NA	2,233
CO_2 pricing for heat and transport (BEHG) (PaM G.1)	CO_2	Contribution to sectoral GHG reduction target for industry until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 140 / 118 Mt CO2eq. in 2030)	Economic	Implemented	CO_2 price on fossil fuels in the heating sector from 2021; increasing price path until 2040.	2021	Federal Government	0	114	1,006
EU ETS innovation fund	CO_2	Contribution to EU 2030 climate & energy framework (at least 40/55% reduction in GHG emissions (from 1990 levels)	Fiscal	Implemented	Financial support for investment in decarbonizing the industrial sector	2020	Federal Government			
National Decarbonisation programme	CO_2	Contribution to sectoral GHG reduction target for industry until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 140 / 118 Mt CO2eq. in 2030)	Fiscal	Implemented	Financial support for investment in decarbonizing the industrial sector	2021	Federal Government			
National Hydrogen Strategy: IPCEI	CO_2	Part of the National Hydrogen Strategy from June 2020	Fiscal	Implemented	Financial support for investment in decarbonizing the industrial sector	2021	Federal Government	0	0	1,045
National Hydrogen Strategy: Pilot programme for Carbon Contracts for Difference	CO_2	Part of the National Hydrogen Strategy from June 2020	Fiscal	Implemented	Financial support for investment in decarbonizing the industrial sector	2021	Federal Government			
Programm for the mitigation and use of CO_2 in basic materials industries	CO_2	Contribution to sectoral GHG reduction target for industry until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 140 / 118 Mt CO2eq. in 2030)	Fiscal	Planned	Financial support for investment in decarbonizing the industrial sector	2022	Federal Government			
Coverage of PFC emissions from primary aluminium production in EU ETS	PFC	No quantified objective for PFCs under the EU-ETS	Economic	Implemented	PFC emissions from primary aluminium production are included in the EU ETS since 2013	2013	Federal Government			209
Reduction of EEG-levy	CO_2	no explicit quantified objective	Fiscal	Implemented	Reduction of levy on electricity from renewable energies	2021	Federal Government	0	37	130
Initiative for Energy Transformation and Climate Protection in SMEs	CO_2	Contribution to energy savings target under Art. 7 EED (Directive 2912/27/EU; amending Directive 2018/2002). Contribution to energy efficiency target under Art. 3 EED and national primary energy savings target (reduction of 30% until 2030 comp. to 2008).	Information	Implemented	Information programme for SMEs	2013	Federal Government	73	80	84
Buildings: heating and cooling										
Building Energy Law (GEG)	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Regulatory	Implemented	Building code defining minimum standards for new buildings and in case of renovation of existing buildings (residential and non-residential); prohibition on installation of new monovalent oil boilers as of 2026.	2020	Federal Government	NA	1,100	3,080
Tax incentives for refurbishment measures (PaM G.3)	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Fiscal	Implemented	Tax incentives for refurbishment measures in existing buildings; tax incentives are focussed on individual measures in owner-occupied apartments and residential buildings	2020	Federal Government	NA	NA	1,590
Promotion of Energy Efficiency and CO_2 Savings in Agriculture and Horticulture	CO_2	no explicit quantified objective	Economic	Implemented	Promotion of energy efficiency and use of renewable energy use on farms	2015	Federal Government	NA	NA	500

Name of mitigation action	GHG (s) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative) (kt CO_2 eq)		
								2020	2021	2025
CO_2 pricing of fossil fuels in the heating (and transport) sector (BEHG), here only heating covered	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Fiscal	Implemented	Introduction of a CO_2 price on fossil fuels in the heating sector (and also for the transport sector, see below) from 2021; predefined price path (with increasing price levels) until 2026; price released from 2027 (market-based pricing); in this PAM, only the impact on the heating sector is covered	2021	Federal Government	NA	0	150
National labelling scheme for existing heating systems	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Information	Implemented	Obligation of chimney sweepers / energy advisers to label existing heating systems that are older than 15 years. The energy label assigns the boiler to a specific energy efficiency class and provides owners with information on energy cost savings and advice on further energy consulting services	2016	Federal Ministry for Economic Affairs and Energy	NA	10	60
Energy consulting for residential buildings	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Information	Implemented	State-subsidized energy consulting for residential buildings (building-specific renovation roadmap aiming at developing, for individual buildings, renovation strategies that are tailored to the buildings' specific situations)	2020	Federal Ministry for Economic Affairs and Energy	NA	10	25
Exemplary role of public buildings (federal level)	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Regulatory	Implemented	Definition of target standards for new buildings and in case of renovations; target renovation rate)	2020	Federal Government	NA	0	25
KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations	CO_2	Contribution to sectoral GHG reduction target for the building sector until 2030 according to the Federal Climate Change Act 2019 / Amended Act 2021 (reduction to 67/42/20 Mt CO2eq. in 2030/2035/2040)	Fiscal	Implemented	KfW (the German government-owned promotional bank) and BAFA provide soft loans and grants for ambitious energy standards for new buildings and renovations (incl. investments in renewable heating technologies); programme covers residential and non-residential buildings	2020	Federal Government	NA	2,300	5
Energy labelling	CO_2	Contribution to EU 2030 climate & energy framework (at least 40/55% reduction in GHG emissions (from 1990 levels) and 32.5% improvement in energy efficiency (comp. to 2007 reference scenario)	Regulatory; Information	Implemented	Mandatory energy labelling	2010	Federal Government	NA	NA	0
Transport										
CO_2 pricing for heat and transport (BEHG) (PaM V.1)	CO_2	Contributes to various objectives	Economic	Implemented	CO_2 price from 2021. Exogenous CO_2 price path (125 €/t in 2030).	2021	Federal Government	NA	1,160	3,450
EU CO_2 standards for heavy commercial vehicles (PaM V.2)	CO_2	30% electric mileage in road freight transport until 2030	Regulatory	Implemented	Update of EU CO_2 standards for trucks according to EU regulation	2021	Federal Government	NA	240	2,530
Update of EU CO_2 standards for passenger cars and light commercial vehicles (PaM V.3)	CO_2	7-10.5 million electric cars by 2031	Regulatory	Implemented	Update of EU CO_2 standards for passenger cars and light commercial vehicles according to EU regulation	2022	Federal Government	NA	0	980
Development of renewable fuels and national implementation of RED II: Adjustment of greenhouse gas quota (PaM V.4)	CO_2	25% renewable energy share in transport by 2030	Regulatory	Planned	Implementation of RED II according to EU regulation	2022	Federal Government	NA	0	790
Reduction of the EEG surcharge from 2021 onwards (PaM V.5)	CO_2	None	Fiscal	Implemented	EEG surcharge to be reduced from 2021 onwards by 2-3 cents per year	2021	Federal Government	NA	80	740
Promotion of light and heavy commercial vehicles with alternative, climate-friendly drive systems	CO_2	30% electric mileage in road freight transport until 2030	Economic	Implemented	Electric trucks are subsidized by up to 40% of the additional costs, up to a maximum of €40,000.	2020	Federal Government	NE	40	630
Increase in air ticket tax	CO_2	None	Fiscal	Implemented	Increase in air ticket tax as of 1 April 2020.	2021	Federal Government	NA	70	90
CO_2 spread of truck tolls	CO_2	30% electric mileage in road freight transport until 2030	Economic	Planned	Integration of CO_2 component in truck tolls from 2023. Zero-emission vehicles will benefit by up to 75% compared with the maximum toll rate.	2024	Federal Government	NA	0	420
Modernization of aircraft fleets	CO_2	None	Economic	Planned	€1 billion subsidy for the acquisition of low-emission aircraft	2021	Federal Government	NA	NA	400
Strengthening rail freight transport	CO_2	Share of rail transport of 25% by 2030	Planning	Implemented	Increase transport performance by rail to around 200 billion tkm in 2040	2020	Federal Government	NE	0	330

Name of mitigation action	GHG (s) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative) (kt CO_2 eq)		
								2020	2021	2025
Electric bus promotion	CO_2	Share of electric city busses 50% by 2030	Regulatory; Economic	Implemented	1,846 million in total funding (2020-2024)	2020	Federal Government	NE	40	310
Stronger weighting of the CO_2 component of the vehicle tax from 2021 onwards	CO_2	None	Fiscal	Implemented	According to vehicle tax law (stronger progression according to CO_2)	2021	Federal Government	NA	80	290
Increase of public transport + regionalization funds, improvement of service quality of public transport (PaM V.8)	CO_2	Doubling of public transport by 2030	Planning; Economic	Implemented	€21 billion in additional funding over the period 2021-2031	2020	Federal Government	NA	80	210
Rail electrification	CO_2	Increasing rail electrification to 70%	Planning	Implemented	Degree of electrification increases from 61% (2019) to 70% (2030)	2020	Federal Government	NE	0	160
Reduction of the VAT on long-distance rail traffic	CO_2	Doubling of passengers in rail transport by 2030	Fiscal	Implemented	Reduction of VAT in long-distance rail transport from 19% to 7% as of 1 Jan. 2020 (price reduction of 10%)	2020	Federal Government	NE	100	120
Inland shipping: abolition of canal dues	CO_2	None	Economic	Implemented	Savings of € 45 million p.a. for inland waterway shipping	2019	Federal Government	NE	90	110
Buyers' premium for electric cars	CO_2	7-10.5 million electric cars by 2030	Economic	Implemented	Implementation in accordance with subsidy directive (federal share of purchase premium up to €6,000), limitation of funds to total amount (€4.69 billion).	2020	Federal Government	NE	50	90
Special depreciation for electrically powered commercial vehicles until 2030	CO_2	30% electric mileage in road freight transport until 2030	Fiscal	Implemented	Special depreciation for electric trucks in the amount of an additional 50% in the year of acquisition until 2030	2020	Federal Government	NE	10	70
Expansion of bicycle infrastructure (paths and parking facilities)	CO_2	Doubling of bike-km by 2030	Planning	Implemented	Additional €900 million in total federal funding for cycling by 2023	2021	Federal Government	NA	0	60
Reduction of company car tax for electric cars until 2030	CO_2	7-10.5 million electric cars by 2031	Fiscal	Implemented	Privately used electric company cars will be taxed at half the list price (PHEV) or a quarter of the list price (BEV), instead of 1% of the list price, until 2030.	2020	Federal Government	NE	0	60
Strengthening long-distance passenger rail services, timetable optimization and digitization	CO_2	Doubling of passengers in rail transport by 2030	Planning	Implemented	Time savings for long-distance rail passengers of 5 % by 2030 and 10 % by 2040	2020	Federal Government	NE	10	60
Inland shipping: use of shore-side electricity in ports	CO_2	50 % of inland vessels will use shore-side electricity by 2030	Fiscal	Implemented	50 % of inland vessels will use shore-side electricity by 2030	2021	Federal Government	NA	0	10
Promoting the development of supply infrastructure for electrified commercial vehicles.	CO_2	30% electric mileage in road freight transport until 2030	Planning	Implemented	Funds for refuelling and charging infrastructure for cars and trucks amounting to €5.6 billion	2020	Federal Government	NE	0	0
Change in the commuting allowance for long-distance commuters	CO_2	None	Fiscal	Implemented	Temporary increase in distance allowance until 2026	2021	Federal Government	NA	-60	-190
Waste management sector, and other areas										
Funding of landfill aeration (PaM W.1)	CH_4	No explicit quantified objective	Economic	Implemented	Rewetting of organic soils (LULUCF)	2013	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety	NE	NE	370
Avoidance of food waste (PaM W.5)	CH_4	Reduction of food waste by 50%	Planning; Information	Implemented	Reduction of bio-waste through less food waste	2019	Federal Government	NE	NE	70

Name of mitigation action	GHG (s) affected	Objective and/or activity affected	Type of instrument	Status of implementation	Brief description	Start year of implementation	Implementing entity or entities	Estimate of mitigation impact (not cumulative) (kt CO_2 eq)		
								2020	2021	2025
Separate collection of biological waste (Kreislaufwirtschaftsgesetz)	CH_4	No explicit quantified objective	Regulatory	Implemented	Separate collection of biological waste (Kreislaufwirtschaftsgesetz)	2015	Federal Government	NE	NE	0
Agriculture										
Increase of share of cattle and pig slurry which is stored in gas-tight tanks to 70% (PaM A.2)	CH_4; N_2O	nA	Economic	Adopted	Emission-reduced storage of manure; renewable energy produced from manure	2021	Federal Government	0.0	NE	1,581.0
Implementation of German Fertilisation Ordinance 2020 (PaM A.3)	N_2O	nA	Regulatory	Implemented	Reduction of farm N surplus	2020	Federal Government and federal states (Länder) (Local)	1,000.0	NE	1,073.0
Increase of organic farming to 20% of total agricultural utilised land (PaM A.5)	N_2O	nA	Economic	Implemented	Reduction of mineral nitrogen application; Reduction of farm N surplus	2019	Federal Government and federal states (Länder) (Local)	65.0	NE	372.0
Implementation of NEC Directive (reduction of ammonia emissions) (PaM A.6)	N_2O	nA	Regulatory; Economic	Implemented	Reduction of the amount of ammonia emitted	2019	Federal Government	200.0	NE	352.0
Reduction of nitrogen balance surplus through the mass flow balance ordinance	N_2O	nA	Regulatory	Adopted	Reduction of farm N surplus	2023	Federal Government and federal states (Länder) (Local)	NA	NA	0.0
LULUCF										
Reduction of peat as substrate in gardening	CO_2	nA	Voluntary/negotiated agreements	Implemented	Voluntary agreements with substrate industry and retailers, research on peat substitutes. See https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/klimaschutzprogramm_2030_en_bf.pdf, chapter 3.4.7.3 Conserving peatland, including curbing peat use in growing media	2019	Federal Government	NE	NE	909
Reduced land use for urban development and transport (PaM F.1)	CO_2	nA	Planning	Implemented	Conservation of carbon in existing forest and grassland	2019	Federal states (Länder) (Local)	NE	NE	1,168
Conservation of grassland (PaM F.2)	CO_2	nA	Regulatory; Economic	Implemented	Prevent the conversion of grassland into other cropland	2019	Federal Government	NE	NE	638
Organic (peatland) soil protection	N_2O	nA	Economic; Planning	Adopted	Rewetting of organic soils (LULUCF)	2021	Federal Government and federal states (Länder) (Local)	NA	NE	1,353

4.6 Climate-policy measures of the Länder and of municipalities

4.6.1 The German Länder (states)

Like the federal government, the German Länder continue to develop their own climate-policy measures and instruments. In the following section, we present the most important changes that have occurred in this regard in the Länder:

4.6.1.1 Baden-Württemberg

Baden-Württemberg adopted its first climate change act in 2013. In 2020, the act was comprehensively updated for the first time, and in fall 2021 the state parliament (Landtag) adopted a further amendment. The climate change act's central element consists of climate protection goals for the years 2030 (reduction by 65 % with respect to 1990) and 2040 (achievement of greenhouse-gas neutrality). In addition, the climate change act contains concrete measures, such as municipal obligations applying to thermal design of buildings, and requirements for installation of rooftop photovoltaic systems on new buildings and buildings that have undergone complete roof renovations. Progress toward the climate goals is being regularly monitored. Such progress is assessed primarily in light of scientifically determined sector goals for 2030. The state government's council of climate experts (Klima-Sachverständigenrat) plays a central role in such assessment. In cases in which it emerges that the climate goals are not being met, the state government adopts additional measures. In future, the integrated energy and climate action concept (IEKK) that the state has been updating at five-year intervals will be supplanted by a climate-measures registry that will serve as the primary steering instrument at the measures level. The climate-measures registry is oriented to decentralised assumption of responsibility, by the ministries responsible for managing measures in the various sectors, and it can be expanded as necessary. This approach is designed to facilitate rapid implementation of emissions reduction measures.

4.6.1.2 Bavaria

Bavaria's climate change act (Bayerisches Klimaschutzgesetz) entered into force on 1 January 2021[126], and it was updated via a state parliament resolution of 13 Dec. 2022. In it, Bavaria commits itself to reducing its per-capita GHG emissions by at least 65 %, with respect to their 1990 levels, by no later than 2030. Also, the state plans to achieve climate-neutrality by no later than 2040. For its part, the state government is seeking to reach climate-neutrality by 2028. The goals are to be achieved via Bavaria's new climate action programme[127]. The nearly 150 measures it includes are grouped into five central action areas: expansion of renewable energies; intensified use of natural CO_2 sinks; eco-friendly construction; sustainable mobility; and CleanTech, climate research and GreenIT. Born out of the awareness that efforts to contain global warming, to adapt to existing climate change and to understand climate change via research are simply different aspects of the overall response, the programme is set up as an interactive climate action programme. In addition to climate-protection measures, therefore, it also includes measures to adapt to climate change, as well

[126] BayKlimaG: Bayerisches Klimaschutzgesetz (BayKlimaG) Vom 23. November 2020 (GVBl. S. 598, 656) BayRS 2129-5-1-U (Art. 1–11) - Bürgerservice (gesetze-bayern.de)
[127] klimaschutzprogramm_2022.pdf (bayern.de)

as climate research measures aimed at improving our understanding of – and our ability to address – climate change and its impacts. The climate action programme is oriented to central climate policy guidelines. The guidelines affirm that climate protection plays an integral role in Bavaria's administrative actions, and that it is taken into full account in all of the Bavarian state government's decisions. This underscores the state government's role-model function for climate protection.

4.6.1.3 Berlin

In the Berlin climate action and Energiewende act (Berliner Klimaschutz- und Energiewendegesetz), which was amended in 2021, the state of Berlin has specified its climate action goals, and the instruments with which they are to be achieved, in a binding manner. The state is seeking to become completely climate-neutral – or at least reduce its GHG emissions by 95 %, in comparison to their 1990 levels – by 2045. The act is complemented by a Berlin energy and climate action programme (Berliner Energie- und Klimaschutzprogramm – BEK) that sets forth the concrete strategies and measures for achieving the goal of climate neutrality. The programme was proposed by the state government, and it was adopted in 2017 by Berlin's House of Representatives (Abgeordnetenhaus). An updated version of the programme will be presented in 2022. Berlin's state government maintains a website on which it provides information about its climate action efforts.[128]

4.6.1.4 Brandenburg

On 23 August 2022, Brandenburg's cabinet adopted a comprehensive framework[2] for a state-specific pathway to climate neutrality by no later than 2045. For the years 2030 and 2040, and for the 2045, the target year for climate neutrality, required reductions in Brandenburg's total GHG emissions were defined (75 percent by 2030; 96 percent by 2040; and 99 percent by 2045, all with respect to 1990 levels). Also, specific required reductions were adopted for the sectors addressed by the Federal Climate Change Act (source balancing): energy, industry, buildings, transport, waste management, and agriculture. With a view to strengthening carbon sequestration in natural sinks, quantitative goals were also defined for the land-use sector: for 2030 (0.6 Mt CO2e), 2040 (1.8 Mt CO2e) and 2045 (2.4 Mt CO2e). As a result, Brandenburg now has an overarching orientational framework in place for all of its individual strategies – and for its measures programme, which is now being prepared, under the Brandenburg climate action plan. Also, on 23 August 2022, the Brandenburg state government adopted an updated energy strategy, its "Energy Strategy 2040"[129]. With this move, the state government has reaffirmed its goal of making its energy system climate-neutral, and it has defined ambitious goals for expansion of use of wind and solar energy: By 2040, Brandenburg plans to have 15 GW of installed wind-energy capacity (wind turbines) and 33 GW of installed solar capacity (photovoltaic systems) in place.

4.6.1.5 Bremen

In Jan. 2020, Bremen's state parliament (Bremische Bürgerschaft) established a commission of enquiry on the issue "Climate Action Strategy for the State of Bremen." In December 2021, that commission presented its final report, with recommendations for ambitious climate protection goals. The goals include reducing Bremen's CO_2 emissions by 60 % by

[128] https://www.berlin.de/sen/uvk/klimaschutz, last checked on 26 Oct. 2022
[2] https://mluk.brandenburg.de/sixcms/media.php/9/Zwischen-und-Sektorziele-des-Klimaplans-Brandenburg.pdf
[129] https://mwae.brandenburg.de/media/bb1.a.3814.de/Energiestrategie2040.pdf

2030, by 85 % by 2033 and by 95 % by 2038, all with respect to the level of the base year 1990. Key database for definition and assessment of these reduction goals a balance sheet of sources prepared in keeping with the methods of the Länder working group on Energy Balances (Länderarbeitskreis Energiebilanzen).

Via resolution of 7 June 2022, Bremen's Senate approved the climate protection goals recommended by the commission of enquiry. An amendment of Bremen's climate action and energy act (Bremisches Klimaschutz- und Energiegesetz – BremKEG), which will enshrine the goals in state law, is currently being prepared.

4.6.1.6 Hamburg

In the framework of a key issues paper on the second update of Hamburg's climate action plan, Hamburg's Senate has adopted ambitious new overarching climate goals, along with specific sub-goals for the sectors private households; industry; transport; and trade, commerce and services. As now envisioned, Hamburg's energy-related CO_2 emissions are to be reduced as follows with respect to the base year 1990:

- by 70 percent by 2030;
- by 98 percent by 2045 – with achievement of net CO_2 neutrality with the help of emissions sinks.

  A second update of Hamburg's climate plan, planned for 2023, will refine the state's strategies and measures in light of these new climate goals.

Also, Hamburg's climate change act is to be amended in 2023. That act enshrines the climate plan goals in law and provides a binding legal framework for climate action. Hamburg is working toward its climate goals via a range of different approaches, including requirements pertaining to public buildings and thermal design, and obligations pertaining to use of renewable energies.

Hamburg has set ambitious goals for successive CO_2-emissions reductions. To achieve them, the state will have to transform its energy system, its resources use and its transport system.[130]

4.6.1.7 Hesse

Working on the basis of a monitoring report, Hesse's state government is currently updating the integrated climate action plan that it adopted in March 2017. The preparation of Hesse's new climate plan, which is oriented toward the year 2030, has also been supported by a comprehensive public-participation process. The plan includes measures for both climate action and adaptation to climate change. In this context, the state has moved its goal of achieving climate neutrality up to 2045, and the state cabinet has adopted sector goals for 2030. Also, the state is preparing Hesse's first climate law, and it is amending Hesse's energy act (Energiegesetz).[131]

[130] Excerpt from: Unsere Ämter - Amt Energie und Klima – Webseite der Behörde für Umwelt, Klima, Energie und Agrarwirtschaft der Stadt Hamburg. As checked on 17 Nov. 2022, URL: https://www.hamburg.de/bukea/energie-und-klima/

[131] Hessian Ministry for the Environment, Climate Protection, Agriculture and Consumer Protection (Hessisches Ministerium für Umwelt, Klimaschutz, Landwirtschaft und Verbraucherschutz 2022)

4.6.1.8 Mecklenburg – West Pomerania

The coalition agreement for Mecklenburg – West Pomerania's current government calls for the preparation of a climate change act for the state. The state is aiming to achieve climate neutrality by 2040, and to make its state administration climate-neutral by 2030. The aim of adaptation to climate change will be enshrined in the new act, along with sector-specific goals and measures. Preparation of the act is being supported by a broad-based public-participation process that includes on-site events, digital conferences and online-participation options. The proposals that emerge from the public-participation process will enter be taken into account in preparation of the draft act.

To provide additional impetus, funding programmes, drawing on both state funds and funds from the European Regional Development Fund (ERDF), are being carried out and updated, to support efforts such as development of climate-action-funding guidelines and installation of plug-in photovoltaic systems.

4.6.1.9 Lower Saxony

In July 2022, Lower Saxony's state government defined the following climate goals, in the framework of the first amendment of the state's climate act: GHG-emissions reductions of at least 65 percent by 2030, and achievement of climate neutrality by 2045. In addition, the state has introduced requirements for all new buildings to be equipped with solar systems, and it has adopted municipal climate-action obligations (including obligations pertaining to thermal design of structures; preparation of climate action concepts for administrations; and to advising regarding funding options).

Lower Saxony's climate action strategy includes implementation strategies for individual sectors. Also, a total of 1 billion euro has been provided for efforts in the framework of a measures programme for climate action[132].

4.6.1.10 North Rhine – Westphalia

The coalition agreement for North Rhine – Westphalia's current government (with the CDU and Green parties; 2022 – 2027) calls for the state to achieve climate neutrality, with net-zero emissions, as quickly as possible, and with an orientation to the 1.5 degree goal for containment of global warming. To this end, an immediate climate action programme is to be presented, covering the areas energy, business and commerce, industry, heat generation, municipalities, municipalities and consumer protection. In addition, the state plans to enhance the effectiveness of its climate change act, and to make its intermediate goal for 2030 (currently, 65 percent with respect to 1990) more ambitious, in the framework of relevant federal provisions. To ensure that it can achieve its climate protection goals, the state plans to establish a climate-protection monitoring system. In October 2022, the state of NRW made a formal decision to phase out lignite-fired electricity generation by 2030.

4.6.1.11 Rhineland-Palatinate

In its "Future agreement for Rhineland-Palatinate, 2021 through 2026" ("Zukunftsvertrag Rheinland-Pfalz 2021 bis 2026"), Rhineland-Palatinate has defined the goal of achieving balance-sheet climate neutrality in a corridor between 2035 and 2040. This goal is considerably more ambitious – 10-15 years earlier – than the existing goal for balance-sheet

[132] Klimaschutz in Niedersachsen | Nds. Ministerium für Umwelt, Energie und Klimaschutz

climate neutrality as set forth in the state's current climate action act. Achievement of the goal is to be supported via definition of sector goals. To that end, an amendment of the state's act for funding of climate action (Landesgesetz zur Förderung des Klimaschutzes) is currently being prepared. Via a "Municipal climate pact" ("Kommunaler Klimapakt"), the state is supporting climate action at the local level. In addition, the state government is setting a good example by working to have its state administration achieve climate neutrality by 2030.

4.6.1.12 Saarland

The state of Saarland set itself the aim of having renewably generating electricity account for a 20 percent of its total electricity consumption by 2020. We were able to achieve that aim, because many stakeholders worked together, and hard, for the further expansion of renewable energies in Saarland.

Now, an "Energy Roadmap 2030" ("Energiefahrplan 2030") is defining new goals for the energy sector, in the areas of energy efficiency and expansion of renewable energies. The Roadmap was approved by the state's council of ministers (Ministerrat) on 7 September 2021. Details on the Roadmap are available at the state's online information about its "Energiebeirat" ("Energy advisory board), a body that played a central role in the Roadmap's preparation. Implementation of all measures in the area of energy efficiency would achieve a CO_2-emissions reduction of up to 500,000 tonnes. An increase in renewable energies' share of electricity generation, to at least 40 percent, would provide additional CO_2 savings of about 1 million tonnes.

In November 2020, Saarland's state government established a special staff position for climate-action coordination within its ministry of economics, with a view to improving use of synergies, identifying and closing gaps in relevant efforts, taking account of strategic aspects, and horizontally dovetailing the various sectors' efforts in this context. With this and other moves, the state is seeking to improve its climate action efforts overall, and to develop and implement measures in all relevant sectors.[133]

As part of its efforts to implement its climate action concept from the year 2008, Saarland's state government launched a state funding programme entitled "Municipal future energy programme" ("Zukunftsenergieprogramm kommunal" – ZEP kom) covering the period 2015-2023. The programme has a budget of 18 municipal euro. An additional programme for funding smart energy-storage systems has been underway since 15 Oct. 2015. It has a budget of 1.5 million euro.

4.6.1.13 Saxony-Anhalt

Saxony-Anhalt is currently implementing central provisions of its government's coalition agreement of 2021. The key climate policy focuses of the coalition agreement include the holding of a "Future and Climate Policy" congress ("Zukunfts- und Klimaschutzkongress"). At such events, and in the framework of numerous specialised workshops and public events, measures within the state's climate and energy concept are evaluated and prioritised in light of current trends, and new measures are discussed. The state government plans to take account of the results emerging from the "Future and Climate Policy" congress, in its efforts toward state, national and European climate protection goals.

[133] Excerpt from: Meilensteine der Klimapolitik - Politische Klimaziele – Webseite des Ministeriums für Wirtschaft, Innovation, Digitales und Energie im Saarland. Last checked on: 17 Nov. 2022, URL: https://www.saarland.de/mwide/DE/portale/energie/klima/klimaschutz/meilensteine.html

4.6.1.14 Saxony

On 1 June 2021, Saxony's state government adopted the "2021 Saxony Energy and Climate Programme" ("Energie- und Klimaprogramm Sachsen 2021" – EKP 2021). The EKP 2021 serves as the strategic framework for Saxony's energy and climate policy. Currently, a measures plan for implementation of the goals and focuses of the EKP 2021 is being prepared.

4.6.1.15 Schleswig-Holstein

On 17 Dec. 2021, an amendment of Schleswig-Holstein's Energiewende and Climate Action Act "Energiewende- und Klimaschutzgesetz) entered into force. It formulates goals and measures relative to the state's climate action goals.[134] In June 2021, the state government presented an Energiewende and Climate Action Report 2021 (Energiewende- und Klimaschutzbericht 2021 – LT-Drs. 19/3063) on relevant goals, measures and indicators. In June 2022, a 2022 monitoring report on the Energiewende and climate action was published on the Internet, in both short and long versions. The 2022 coalition agreement of the state's governing coalition calls for Schleswig-Holstein to become the first climate-neutral industrialised state – and to achieve this goal by 2040. In a Climate Action Programme 2030 (Klimaschutzprogramm 2030), the state government plans to present the measures it will use, at the state and federal levels, to meet its emissions-reduction and renewables-expansion goals for 2030 in Schleswig-Holstein.

4.6.1.16 Thuringia

Thuringia's "Thuringian Act on climate action and for adaptation to the impacts of climate change" ("Thüringer Gesetz zum Klimaschutz und zur Anpassung an die Folgen des Klimawandels" – Thüringer Klimagesetz) has been in force since the end of 2018. The climate act is complemented by measures and additional goals set forth by the integrated energy and climate action strategy adopted by the state government in 2019. The results of these efforts are to be evaluated in 2023.

4.6.2 Municipalities

In keeping with the principle of local self-government, municipalities have the option – outside of the requirements of any federal or state laws – of taking actions of their own in the area of climate protection. That said, some states' (Länder) climate change acts require municipalities to collaborate on certain measures.

Via municipal guidelines in its "National Climate Protection Initiative" funding programme, the federal government supports climate action activities of rural districts, cities and towns. Other federal funding programmes also support climate action measures at the municipal level – as well as other types of measures. Among these are programmes in the areas of "Energy-efficient urban refurbishment" ("Energetische Stadtsanierung") and "Urban Development Promotion" ("Städtebauförderung").

[134] The Energiewende and Climate Action Act (Energiewende- und Klimaschutzgesetz) is available here; a summary is available here.

In addition, the support and network services described in the 6th National Communication are still in place. These include, for example, the Service and Competence Centre: Municipal Climate Action (Service- und Kompetenzzentrum: Kommunaler Klimaschutz).

4.7 Avoidance of adverse impacts of climate-protection measures, especially on developing and emerging countries

Article 2 (2) of the Kyoto Protocol requires the Annex I Parties to strive to implement policies and measures in such a way as to minimize adverse effects, including the adverse effects of climate change, effects on international trade, and social, environmental and economic impacts on other Parties, especially developing country Parties.

The ambitious national reduction targets set forth by the Federal Climate Change Act (cf. Chapter 4.1) are being met via reduction of GHG emissions in Germany. Use of emissions reduction units pursuant to Article 6 of the Kyoto Protocol, resulting from projects aimed at reducing anthropogenic emissions by sources or enhancing anthropogenic removals by sinks of greenhouse gases in other countries, is not being taken into account in this regard.

In addition, Germany is providing support – financial assistance and technology cooperation – to developing and emerging countries, and countries undergoing transformation, in their efforts to combat climate change and adapt to its impacts. These activities are described in detail in Chapter 6.

4.8 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 GHG projections presented here, for the years 2025, 2030, 2035 and 2040, are based on the 2021 Projections Report. A research consortium from Öko-Institut, the Fraunhofer Institute for Systems and Innovation Research (ISI) and the firm of IREES GmbH has prepared these projections under commission to the German Environment Agency. The projections for the agriculture and LULUCF sectors were calculated by the Thünen Institute. As a Member State of the European Union, Germany is required to report national projections of anthropogenic GHG emissions every two years, by 15 March of relevant years (most recently, by 15 March 2021) (2021 Projections Report). By doing so, Germany fulfils EU requirements pertaining to European emissions reporting pursuant to Article 18 of EU Regulation 2018/1999 and Sec. 10 (2) of the German Federal Climate Change Act in its version of 2019.

For the projections, a with-measures scenario (WMS) was prepared that takes account of the climate-policy and energy-policy measures that, as of 31 August 2020, had been introduced or significantly modified in the various sectors concerned. The pertinent methods are described in Chapter 5.2.

5.1 Projection of total GHG emissions, by sectors and types of gas

In the national projection, excluding international aviation and maritime transport, and land use, land-use change and forestry (LULUCF), emissions will decrease by about 49 % by 2030, with respect to 1990 levels (-36 % with respect to 2005 levels) and by about 67 % by 2040, with respect to 1990 levels (-59 % with respect to 2005 levels) (cf. Figure 24). In light of the sensitivities considered in the report, an emissions-reduction corridor emerges for 2020 that, with regard to the relevant 1990 levels, lies between 33.7 % (stronger economic growth) and 37.5 % (lower electricity-export balance). An overview of emissions trends in the WMS, broken down by Federal Climate Change Act (KSG) sectors, is provided in Figure 25 and Table 9 (cf. Chapter 5.1.2).

It is important to note, in this connection, that the described emissions trends do not take account of trends in international aviation (and, to a lesser extent, in maritime transport). In particular, as a result of rapid growth in international aviation, that sector's GHG emissions are seen to increase by more than 4 Mt CO2e in the period 2005 – 2020, or by about 14 %. Since in the WMS no additional measures relative to international transports are assumed, this conclusion holds for both scenarios, to the same degree.

Tables with the results of the GHG emissions projections are provided in sections 5.1.1 and 5.1.2.

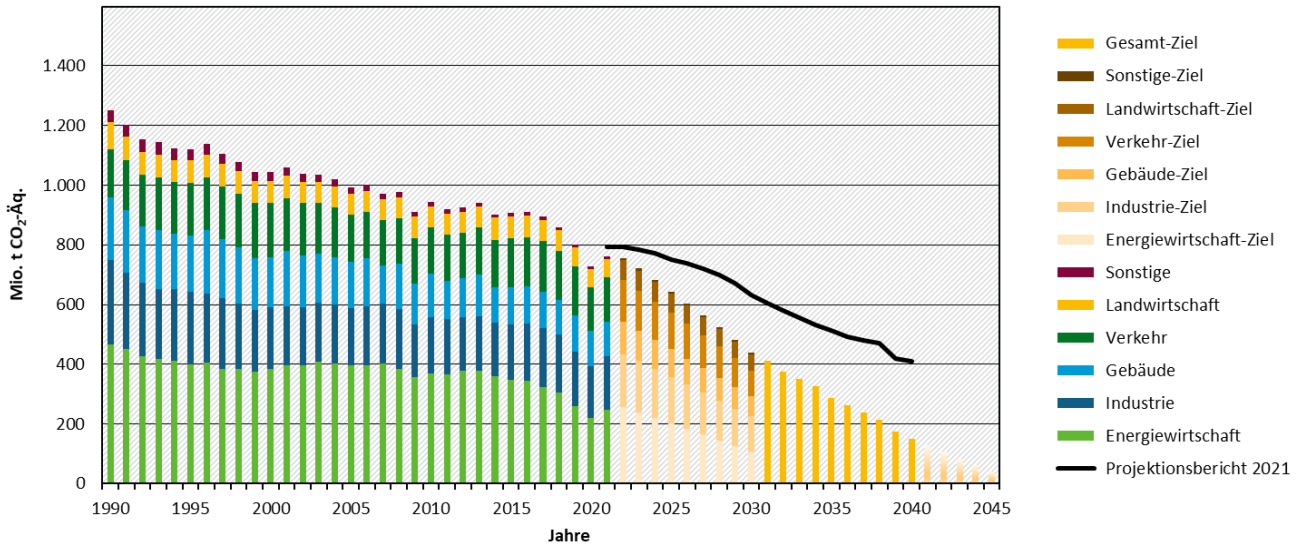


Figure 24: Historic GHG emissions (1990-2020), and projections of GHG emissions (2021-2040) by source categories (including targets pursuant to Federal Climate Change Act)

In the following section, the aggregated development of GHG emissions in the WMS is presented in two ways. In one, the contributions of the various greenhouse gases are shown; in the other, the contributions of the individual source categories are shown. In each case, the total GHG emissions are shown without inclusion of the emissions contributions 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 GHG 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.

5.1.1 Development of GHG emissions, by greenhouse gases

CTF Table 6(a) presents data on emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). This summary does not include greenhouse gas emissions from international fuel bunkers (deep-sea shipping and international aviation) and LULUCF.

By 2018, GHG emissions were already 31 % down on 1990, and nearly 14 % down on 2005, in the national balance. Compared with the 1990 reference year, total GHG emissions fall by 49 % by 2030 (a full -36 % with respect to 2005 levels) – from 1,249 to about 633 Mt CO2e; by 2040, they fall by 67 % (-59 % with respect to 2005), to about 409 Mt CO2e. The German government's goal to reduce greenhouse gas emissions by 65 % by 2030, and by 88 % by 2040, compared with 1990, is thus not achieved under the with-measures scenario.

Between 1990 and 2018, annual emissions of carbon dioxide[135] were cut by a full 28 %. In 2040, CO_2 emissions will be 68 % lower than they were in 1990. Both historically and in the

[135] CO_2 emissions from incineration of biomass are not included here or in any of the CO_2 emissions discussed in this report.

projection, CO_2 is the gas with the largest share in Germany's total greenhouse gas emissions.

The greatest reductions in methane emissions have already been achieved in the past: CH_4 was the most important greenhouse gas in 1990, after CO_2, with a share in total emissions of almost 10 %. But since CH_4 emissions were reduced by 57 % by 2018, their share in total emissions fell to only slightly more than 6 %. By 2040, CH_4 emissions are nearly 67 % down on 1990. However, since the emissions reductions here are disproportionately low, especially after 2030, their percentage rises again slightly, to 10 %, up to 2035.

Nitrous oxide's share in total greenhouse gas emissions was a full 5 % in 1990. Here too a significant emissions cut – about 43 % – was achieved by 2018, with the result that its share of total emissions decreased from 5 % to 4 %. As is the case for methane, almost no further emissions reductions have occurred for nitrous oxide. In 2040, N_2O emissions will be 53 % down on 1990. For this reason, nitrous oxide emissions' share increases again, to a full 7 % in 2035.

In 1990, fluorinated gases accounted for 1.1 % of total greenhouse gas emissions; by 2018, this figure had risen to 1.7 %. By 2040, their share will decrease to 1.0 %.[136]

The reductions with respect to the base-year emissions of the Kyoto Protocol (for CO_2, CH_4 and N_2O, it applied the emissions of 1990, while fluorinated gases it applied the emissions of 1995) are slightly higher, in each case, than the emissions reductions with respect to the year 1990.

[136] Among the fluorinated greenhouse gases, the group of hydrofluorocarbons (HFCs) was the most important in 2018. HFC emissions increased more than fourfold between 1995 (the reference year for fluorinated greenhouse gases) and 2016. But HFC emissions will decrease again significantly in future, with the result that in 2040 an emissions level of 70 % below the 2018 level will be reached. That level will still be higher than the level in the base year 1995, however. Emissions of perfluorocarbons (PFC) were already reduced by 86 % by 2018, with respect to 1990 levels; only slight additional PFC emissions reductions can be expected in future. Emissions of sulphur hexafluoride (SF_6) were reduced by about 40 % by 2018, with respect to 1990. Large additional decreases are expected in future, however, to the extent that SF_6 emissions could fall by about 93 % by 2040, with respect to 1990. By 2018, the gas mix consisting of HFC and PFC (not broken down by shares for the two types of gases) was already more than 97 % below its 1995 level. It can be expected to remain at about this reduced level. Emissions of nitrogen trifluoride (NF_3) reached their maximum in 2010. In 2018, they were still several times higher than they had been in 1995. In future, the importance of NF_3 will become negligible, however.

Table 9: Development of total combustion-related GHG emissions, by gases, 1990-2040

	1990	2005	2018	2025	2030	2035	2040
Mt CO2e							
CO_2 emissions							
Development, 1990 – 2018	1,004.1	839.0	736.4				
With-measures scenario				646.2	544.0	430.6	329.3
CH_4 emissions							
Development, 1990 – 2018	6.7	2.2	4.2				
With-measures scenario				3.8	3.7	3.6	3.5
N_2O emissions							
Development, 1990 – 2018	7.3	5.3	5.8				
With-measures scenario				5.1	4.3	3.6	2.7
Total, CO_2 + CH_4 + N_2O							
Development, 1990 – 2018	1,018.0	846.5	746.4				
With-measures scenario				655.2	552.1	437.8	335.6
Total, CO_2 + CH_4 + N_2O	Change as of 1990, in %						
Development, 1990 – 2018		-16.9	-26.7				
With-measures scenario				-33.6	-45.8	-57.0	-67.0
Total, CO_2 + CH_4 + N_2O	Change as of 2005, in %						
Development, 1990 – 2018			-11.8				
With-measures scenario				-22.6	-34.8	-48.3	-60.4

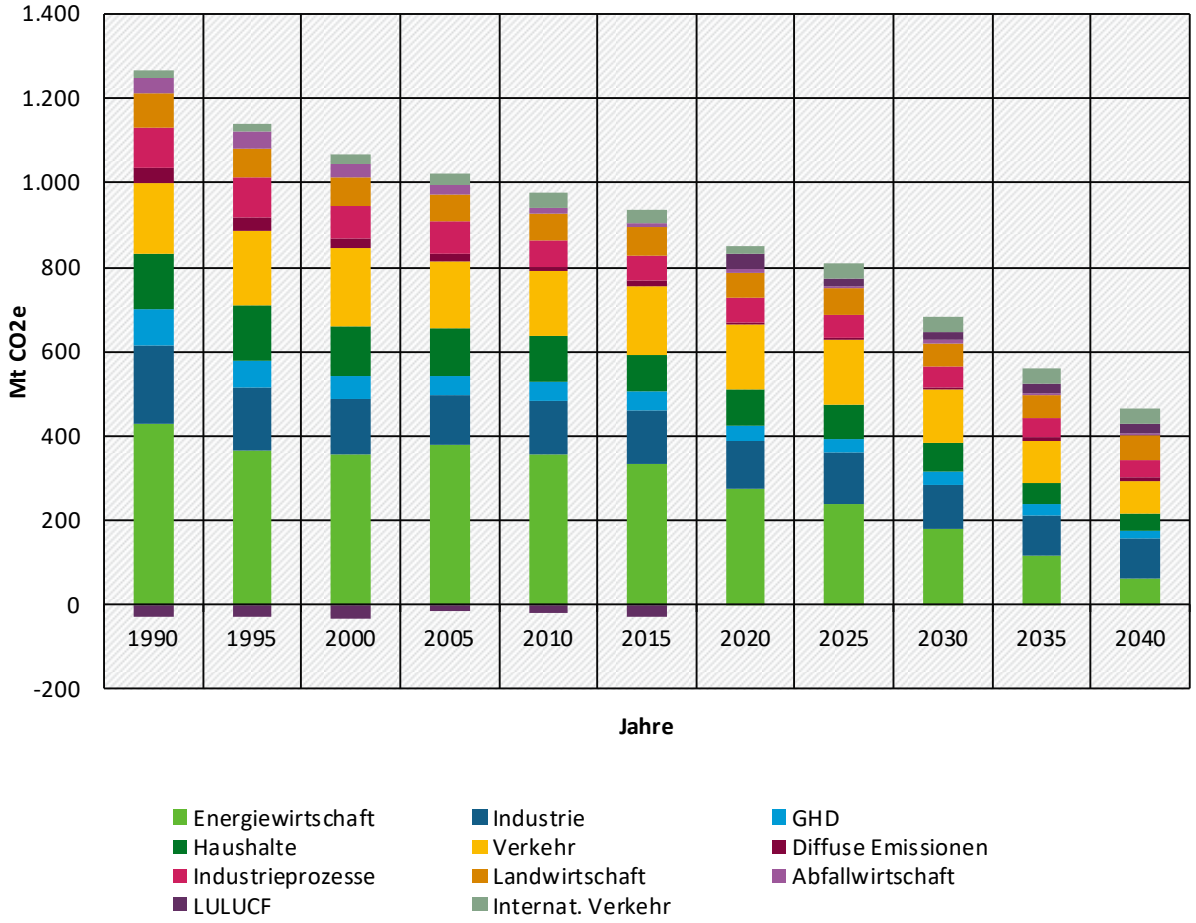
Note: Only energy-related emissions, as broken down in the NIR; with CO_2 emissions from flue-gas desulphurisation, and including international aviation and deep-sea shipping

Source: (UBA 2020a, 2020c)Model calculations of Fraunhofer ISI, IREES and Öko-Institut

5.1.2 Development of GHG emissions, by source categories

In the national projection, excluding international aviation and deep-sea shipping, and land use, land-use change and forestry (LULUCF), emissions will decrease by about 49 % by 2030, with respect to 1990 levels (-36 % with respect to 2005 levels) and by about 67 % by 2040, with respect to 1990 levels (- 59 % with respect to 2005). Table 10, Figure 25 and CTF Table 6a present an overview, structured by categories, of emissions trends in the with-measures scenario.

Figure 25: Development of total GHG emissions in the with-measures scenario (WMS) (1990–2040)



Source: Öko-Institut

Table 10: Development of total GHG emissions in the with-measures scenario (WMS) (1990– 2040)[137]

By category

(Mt CO2e)	1990	2005	2010	2018	2025	2030	2035	2040
Energy	685.4	555.3	521.5	426.5	355.1	288.3	208.3	128.9

[137] translation: categories = energy industries, industry (energy-related), commercial/institutional, haousholds, transport, fugitive emissions, industrial processes, agriculture, waste management, LULUCF, international transport

(Mt CO2e)	1990	2005	2010	2018	2025	2030	2035	2040
Energy industry	427.4	379.4	356.0	295.2	234.5	185.3	127.9	67.9
Commercial and institutional	88.4	47.9	47.6	39.1	35.0	29.5	23.1	18.1
Residential	131.9	112.0	107.0	83.7	78.6	66.8	51.0	36.9
Fugitive emissions from fuels	37.7	16.1	10.9	8.5	7.0	6.759	6.4	6.0
Transport	**165.0**	**161.5**	**154.4**	**163.6**	**152.7**	**127.6**	**101.2**	**79.7**
Industry	**281.5**	**191.0**	**188.2**	**194.2**	**174.8**	**154.6**	**142.8**	**139.4**
Industry (energy)	186.7	115.3	125.6	130.1	119.3	106.8	97.5	94.9
Industrial processes	94.8	75.6	62.6	64.8	55.5	47.8	45.7	44.5
Agriculture	**79.3**	**64.2**	**63.6**	**63.6**	**61.6**	**57.3**	**57.3**	**57.3**
Waste management	**38.3**	**21.3**	**14.6**	**9.7**	**6.7**	**5.0**	**4.0**	**3.4**
Total	**1,249.5**	**993.2**	**942.3**	**858.3**	**750.9**	**632.9**	514.0	408.7
Change with respect to 2005	**25.8%**	**0.0%**	**-5.1%**	**-13.6%**	**-24.4%**	**-36.3%**	-48.2%	-58.8%
Change with respect to 1990	**0.0%**	**-20.5%**	**-24.6%**	**-31.3%**	**-39.9%**	**-49.3%**	-58.9%	-67.3%
Change with respect to base year[a]	**-0.3%**	**-20.7%**	**-24.8%**	**-31.5%**	**-40.1%**	**-49.5%**	-59.0%	-67.4%
Reported as memo items:								
LULUCF	-28.8	-13.4	-19.7	-26.9	16.9	22.3	23.0	21.9
International aviation and maritime transports	18.7	30.4	32.8	34.7	35.1	36.0	37.1	38.0
Total, including memo items	1,239.3	1,010.3	955.5	866.1	802.9	691.3	574.2	468.6
Change with respect to 2005	**22.7%**	**0.0%**	**-5.4%**	**-14.3%**	**-20.5%**	**-31.6%**	-43.2%	-53.6%
Change with respect to 1990	**0.0%**	**-18.5%**	**-22.9%**	**-30.1%**	**-35.2%**	**-44.2%**	-53.7%	-62.2%
Change with respect to base year[a]	**-0.3%**	**-18.7%**	**-23.1%**	**-30.3%**	**-35.4%**	**-44.4%**	-53.8%	-62.3%

Source: 2021 Projections Report for Germany pursuant to Regulation (EU) No 525/2013 [138]

The energy industry accounts for the largest share of the emissions reductions achieved from 2018 through 2040. In this sector, emissions fall in absolute terms by 110 Mt CO2e by 2030, compared with 2018, and by 227 Mt CO2e by 2040. That equates to a 37 % reduction in 2030 with respect to 2018 (-57 % with respect to 1990), and to a 77 % reduction in 2040 (-84 % with respect to 1990). In both 1990 and 2016, the energy industry's share of

[138] Online: https://www.bmuv.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/projektionsbericht_2021_bf.pdf

total emissions (not including international transport and LULUCF) was 34 %. By 2040, the energy industry's share decreases to just short of 17 %.

From 2018 through 2030, energy-related industrial emissions decrease by 23 Mt CO2e, or about 18 % (43 % below the 1990 level). Thereafter, they decrease by 35 Mt CO2e, or 27 %, by 2040, with respect to 2018 (-49 % with respect to 1990). Overall, industrial emissions' share rises from over 15 % in 2018 to nearly 23 % in 2035. GHG emissions of the sector trade, commerce and services decrease by nearly 10 Mt CO2e, or 25 %, by 2030, with respect to 2018 (-67 % with respect to 1990). Then, they decrease by 21 Mt CO2e, or 54 %, by 2040, with respect to 2018 (-80 % with respect to 1990). The trade, commerce and services sector's share in total emissions decreases from 5 % to 4 %. A significant contribution to the projected reduction in emissions comes from private households: with respect to 2018, they reduce their emissions by 20 %, or 17 Mt CO2e, by 2030, (-49 % with respect to 1990), and by 56 %, or 47 Mt CO2e, by 2040 (-72 % with respect to 1990). Furthermore, private households' share falls from 10 % in 2018 to 9 % in 2040. The second-largest contribution to the projected emissions reduction occurs in the transport sector: with respect to 2018, its emissions decrease by 22 %, or 36 Mt CO2e, by 2030 (23 % with respect to 1990), and by 84 Mt CO2e, or 51 %, by 2040 (-52 % with respect to 1990). Historically, transport emissions' share of total emissions shows a rising trend: whereas in 1990 transport's share of total emissions was still a little over 13 %, it rose to 19 % by 2018. In the projection, this trend is stopped, and the transport sector's share no longer rises. In 2040, it is also at 19 %. That said, it must be noted that, due to the expansion of electromobility, some of the emissions from the transport sector are shifted to the energy industry, because public electricity generation is accounted for in the latter. Reductions in fugitive emissions from the energy sector are low in absolute terms, but high in relative terms: emissions reductions of 2 Mt CO2e from 2018 to 2030, and of 3 Mt CO2e by 2040, equate to decreases, with respect to 2018, of 21 % in 2030 (-82 % with respect to 1990) and 29 % in 2040 (-84 % with respect to 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 2018, industrial processes' share was still at nearly 8 %; by 2040, it rises to nearly 11 %. Overall, emissions from industrial processes, with respect to their level in 2018, decrease by 17 Mt CO2e by 2030, or 26 % (-50 % with respect to 1990), and by 20 Mt CO2e, or 31 %, by 2040 (-53 % with respect to 1990). While emissions from agriculture did decrease between 1990 and 2018, their decrease was considerably smaller, and slower, than the decreases seen in all other sectors. Furthermore, agriculture is the sector with the lowest projected emissions reduction: with respect to 2018, by 6 Mt CO2e, or 10 %, by 2030 (-28 % with respect to 1990). After 2018, its emissions remain at a nearly constant level. This implies that agriculture's share of total emissions increases from just over 6 % in 1990 to over 7 % in 2018 and to about 14 % in 2040. Waste management is the sector with the historically highest emissions reductions in relative terms, experiencing an almost 75 % decline in emissions between 1990 and 2018. Nevertheless, emissions from the waste management sector are reduced by a further 5 Mt CO2e, or 48 %, between 2018 and 2030, and by fully 6 Mt CO2e, or 65 %, by 2040, with respect to 2016. This means that waste management continues to be the sector with the greatest emissions reductions in relative terms – 87 % in 2030 and 91 % in 2040 (compared with 1990 levels). The slow decrease in agricultural emissions, and only slight decrease, in absolute terms, in emissions from the waste management sector, explain the below-average decrease in methane and nitrous oxide emissions described in section 5.1.2.

Whereas in the past the LULUCF sector was an overall sink, in the projection it is a source of emissions. It has emerged, however, that trends for forest land, pursuant to the inventory data, diverge from the trends as projected in past projections reports. The projected sink performance of forest land – and, thus, of the entire LULUCF sector – was considerably lower than was determined by the 2017 Carbon Inventory. In part, this is due to the methods involved. A review of the underlying assumptions and scenarios, and adjustment and refinement of the modelling tools used for forest land, are planned for the next report. At present, the 2021 Projections Report's projections for the LULUCF sector are not sufficiently informative with regard to trends for forest land as a sink.

Emissions from the proportion of international aviation and international maritime transport that is attributable to Germany rose by over 86 % between 1990 and 2018. With respect to the year 2018, these emissions will rise by an additional 1 Mt CO2e, or 4 %, by 2030, and they will increase by 3 Mt CO2e, or 10 %, by 2040. This means that emissions from international aviation and international maritime transport will be

93 % higher in 2030 than they were in 1990, and that in 2040 they will even be more than twice as high as in 1990.

Taking account of emissions from LULUCF and international aviation and maritime transport, emissions in 2018 were 30 % lower than they were in 1990, and 14 % lower than they were in 2005. With respect to 1990 levels, they decrease by 44 % by 2030 (-32 % with respect to 2005 levels), and by 62 % by 2040 (-54 % with respect to 2005).

5.2 Methodological approach

The projections report includes a with-measures scenario (WMS). That scenario includes all climate action measures that, by the reference date 31 August 2020, had already been adopted and implemented to the extent that all data and other information required for parametrisation of the measure were available when the modelling began. At the time modelling began, in fall 2020, the GHG inventory for the year 2018 was available. On 15 January 2021 as planned, the German Environment Agency (UBA) published complete, official and detailed inventory data on GHG emissions in Germany, for the year 2019, by transmitting the data to the European Commission. Since modelling takes about two months to complete, compliance with reporting deadlines necessitated commencing the relevant calculations in fall 2020, with the result that it was not possible to take the 2019 inventories into account. The process of parametrisation of the measures was coordinated with the relevant departments. Consequently, in addition to the instruments that have already been in place for some time – in particular, regulatory and economic instruments – the WMS includes a) the measures of the Climate Action Programme 2020 (APK 2020), which the federal government adopted on 3 December 2014 and which also includes the measures of the National Action Plan on Energy Efficiency (NAPE), and b) the measures of the Climate Action Programme 2030 (KSPr 2030), which was adopted on 9 October 2019. It also takes account of additional measures of the Energy Efficiency Strategy 2050 (EffSTRA), which was adopted by the Federal Cabinet on 18 December 2019 – measures which go above and beyond the measures of the Climate Action Programme 2030 – and the GHG-relevant measures of the federal government's economic stimulus package of 3 June 2020. Both cross-cutting and sectoral measures are taken into account. For the most part, the effects of cross-cutting measures are quantified at the sectoral level. Also, a number of supporting measures was taken into account on both levels – in particular, informational instruments.

While such instruments enter into the scenarios, their effects are not separately quantified; instead, they are quantified via the effects of other instruments – normally, economic or regulatory instruments – that (i.e. the effects) they support.

No without-measures scenario was calculated, since an updated climate action programme was adopted at the time the modelling was carried out. In the framework of the 2021 Projections Report, no self-contained without-measures scenario was calculated. On the other hand, the effects of individual measures in the sectors were studied, in some cases, by making assumptions regarding the ways the sectors would have developed in a fictive world without the relevant policies. Since some of the policies and measures involved have been in force for a considerable period, it can become unfeasible to project trends without their impacts.

In the process, emissions of the following greenhouse gases, which are covered by the Kyoto Protocol, were taken into account: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFC), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). This was done for the source categories energy, industrial processes, product use, agriculture, waste management and land-use changes and forestry.

5.2.1 Methodological approach for the emissions projections, and changes since the last Biennial Report

The process of analysing and evaluating the different measures, calculating sectoral 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 – approaches and models which permit an adequate analysis based on the data and information available for the sectors concerned.

For energy-related greenhouse gas emissions from combustion processes, the analyses are based on a complex system of different models (cf. Figure 26)[139]:

a) Electricity generation from fossil fuels and from renewable energy sources is analysed using Öko-Institut models (ELIAS/PowerFlex). Heat generation in CHP systems is also modelled with those models.

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) Modelling for the transport sector is carried out with Öko-Institut's TEMPS model.

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) is used. The effects of individual policy instruments are assessed by Öko-Institut, on the basis of existing evaluations or analyses of the relevant instruments.

e) Analyses for the remaining fuel and electricity demand in the buildings sector are carried out using the FORECAST model platform of Fraunhofer ISI.

[139] The EEA data server also holds a fact sheet on the models used: http://cdr.eionet.europa.eu/de/eu/mmr/art04-13-14_lcds_pams_projections/projections/

f) The analyses for the electricity and fuel requirements of industry and the trade, commerce and services sector are carried out using Fraunhofer ISI's FORECAST model platform, which is based on individual sector models.

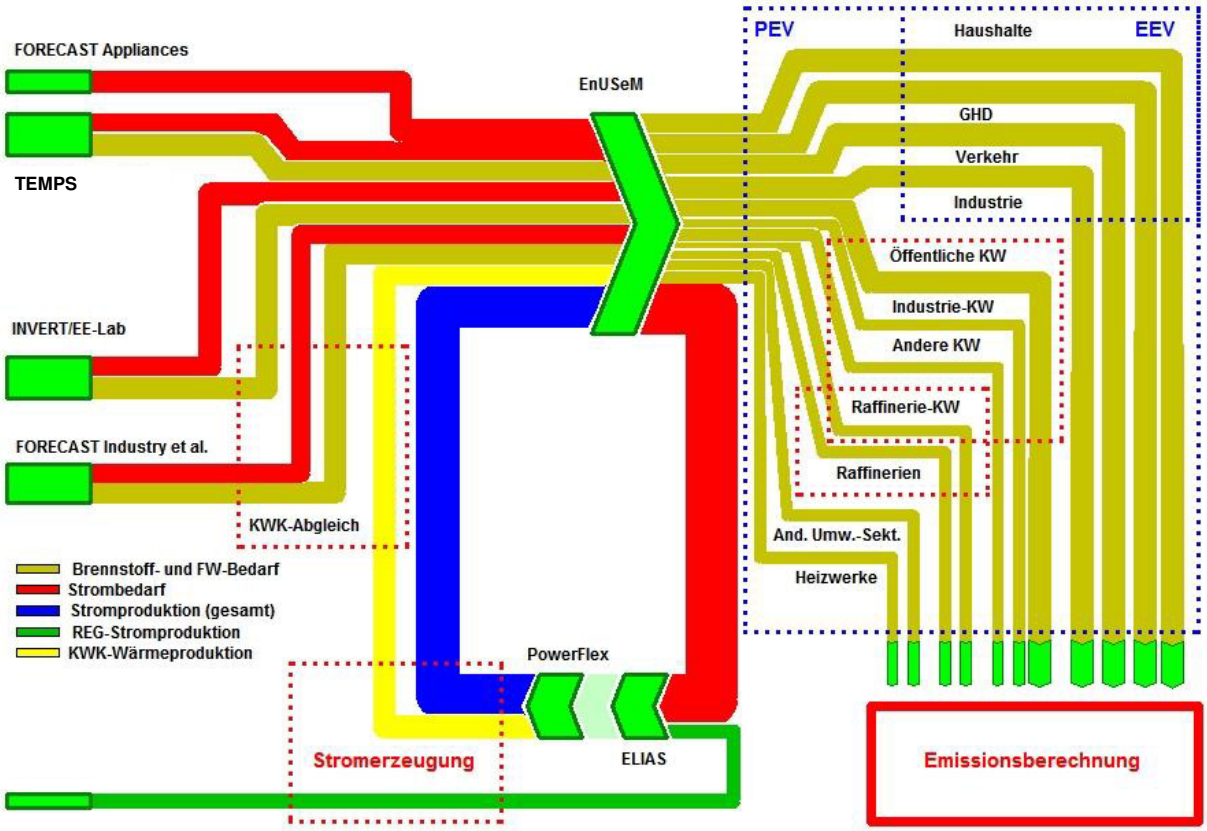


Figure 26: Overview of models used to analyse energy-related greenhouse gas emissions; Source: Federal government (2017)

g) Greenhouse gas emissions from combustion processes are determined using Öko-Institut's emissions model, which evaluates emissions aspects of the energy demand projections aggregated in EnUSEM for the various end-use and transformation 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.

The following approaches are used for emissions from industrial processes:

h) Process-related emissions of the mineral industry and the chemical industry (with the exception of the petrochemical industry) are modelled with the help of the FORECAST model.

i) For the remaining process-related emissions connected with the energy sector, emissions are determined with Öko-Institut's ENUSEM emissions model, on the basis of energy-demand and supply volumes, and using the methods employed for the National Greenhouse Gas Inventory.

j) For process-related emissions that are not connected with the energy sector, emissions are determined with Öko-Institut's ENUSEM emissions model, on the basis of production estimates, and on the basis of the methods employed for the National Greenhouse Gas Inventory.

k) For HFC, PFC, SF_6 and NF_3 emissions, existing projections are updated and adjusted.

Projections of GHG emissions from agriculture, and from Land Use, Land Use Change and Forestry (LULUCF), with regard to agricultural soils, animal husbandry and other areas, are calculated by the Thünen Institute. Energy consumption in agriculture was determined by Öko-Institut, using the LaWiEnMod model. Emissions of the Land Use, Land Use Change and Forestry (LULUCF) sector were calculated by the Thünen Institute.

With regard to GHG emissions from the waste management sector, Öko-Institut's IPCC Waste Model, which is used for preparation of National Greenhouse Gas Inventories, was expanded for the necessary projections.

The scenario calculations rely extensively on the National Greenhouse Gas Inventory. The most recent Greenhouse Gas Inventory available at the time this scenario was calculated was that from the 2020 reporting year. It was prepared in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* using global warming potentials (GWP) in keeping with the current guidelines for inventories (UNFCCC 2013). It contains data for the years 1990 to 2018. The primary data sources used to prepare this report are the historical data in the Greenhouse Gas Inventory (UBA 2020a)[140] and data – consistent with the inventory – downloaded from the Central System for Emissions (ZSE) at the German Environment Agency (UBA 2020b)[141]. The Greenhouse Gas Inventory is not completely compatible with the Energy Balance for the Federal Republic of Germany (in part, due to differences in sector definitions and fuel aggregations). Therefore, there are some differences between the Inventory and the Energy Balance. 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. A more-detailed description of the methods used is provided in the 2021 Projections Report, which is available on the EEA data server[142].

The basic structure of the sector and integration models has not changed since the last National Communication. One significant methodological change that has been made with respect to preceding reports, in the modelling for the Projections Report (in this case, the 2021 Projections Report) is that emissions are now broken down – with respect to the EU-ETS, ESR and, within the ESR, to the national emissions trading scheme – by specific fuels, in the individual subsectors of the energy system. Minor improvements were made in the modelling for the sectors, and they have led to greater precision in calculations for the various policy instruments.

Since the last National Communications, the structure for reporting source categories has been switched from the CRF format to the sector structure used in the Federal Climate Change Act (KSG). As a result, the source categories are not always comparable. Table 11 shows how Greenhouse Gas Inventory source categories (CRF categories) are assigned to

[140] German Environment Agency (Umweltbundesamt 2020): Submission under the United Nations Framework Convention on Climate Change and the Kyoto Protocol 2020. National Inventory Report on the German Greenhouse Gas Inventory, 1990 – 2018, German Environment Agency – UNFCCC Submission.
[141] German Environment Agency (Umweltbundesamt 2020): Central System of Emissions (CSE). Data download; last revision: 1 September 2020.
[142] https://reportnet.europa.eu/public/country/DE

Federal Climate Change Act (KSG) sectors. In addition, the table shows the correlations with the inventory structure pursuant to UNFCCC and the Governance Regulation.

Table 11: Allocation of CRF categories to Federal Climate Change Act (KSG) sectors, and to the inventory structure pursuant to the UNFCCC and the Governance Regulation

CRF category	Federal Climate Change Act (KSG) sector	UNFCCC / Governance Regulation	Remarks
1.A.1.a Public electricity and heat production	Energy industry	Energy industry	District heating plants and electricity and heat production of power plants
1.A.1.b Petroleum refining	Energy industry	Energy industry	Refinery power stations and combustion
1.A.1.c Manufacture of solid fuels and other energy industries	Energy industry	Energy industry	Includes, inter alia, Coking plants, briquette factories, drive systems in coal mining, other power stations of the energy industry
1.A.2 Manufacturing industries and construction	Industry	Industry	Industry boilers, process combustion and industrial power stations that are not included in 1.A.1.b or 1.A.1.c
1.A.3.a Domestic aviation	Transport	Transport	
1.A.3.b Road transportation	Transport	Transport	
1.A.3.c Railways	Transport	Transport	
1.A.3.d Domestic navigation	Transport	Transport	Inland and coastal shipping
1.A.3.e Other transportation	Energy industry	Transport	Natural gas pipeline compressors
1.A.4.a Commercial / institutional	Buildings	Commercial / institutional	
1.A.4.b Residential	Buildings	Private households	
1.A.4.c Agriculture/forestry/fishing	Agriculture	Commercial and institutional	Energy-related emissions
1.A.5. Other	Buildings	Commercial / institutional	Military (stationary and mobile)
B. Fugitive emissions from fuels	Energy industry	Fugitive emissions from fuels	
1.D.1 International aviation and maritime transport	None	None	

CRF category	Federal Climate Change Act (KSG) sector	UNFCCC / Governance Regulation	Remarks
2 Industrial processes	Industry	Industrial processes and product use	Including product use
3 Agriculture	Agriculture	Agriculture	Biological-chemical emissions
4 Land Use, Land Use Change and Forestry	Land use and forestry	LULUCF	
5 Waste and wastewater	Waste management sector, and other areas	Waste management	Waste incineration is included in energy industry and industry

Source: Öko-Institut

5.2.2 Summary of framework data

A number of important frameworks play a central role in development of energy-demand and emissions scenarios. These include demographic and economic framework data and data on the development of energy prices.

The with-measures-scenario (WMS) projections within the 2021 Projections Report, for German GHG emissions through 2040, are made on the basis of assumptions, agreed on by the various participating departments, for

- Population trends,
- Development of the economy and of economic structures,
- Development of energy prices,
- Policies and measures, and
- Technical and sector-specific factors.

All development pathways (with the exception of prices under the Fuel Emissions Trading Act (BEHG)) are summarised in Table 12.

Table 12: Summary of the framework data in the 2021 Projections Report

	Framework data					
	Population, in millions					
	2019	2020	2025	2030	2035	2040
2021 Projections Report[a]		83.2	83.6	83.8	83.8	83.5
Sensitivity, 2021 Projections Report[a]		83.4	84.1	84.3	84.3	84.2
	Annual GDP growth rates for Germany, in various projections					

2021 Projections Report [b]	-	5.5%	1.0%	0.8%	1.0%	1.3%
Sensitivity, 2021 Projections Report [b]	-	-6.5%	0.9%	0.8%	1.0%	1.3%
	Energy-price projections for crude oil, natural gas and hard coal, with regard to prices of the year 2016 (€/GJ), 2019–2040					
Crude oil[c,d]	**9.4**	**5.9**	**10.3**	**11.1**	**11.8**	**12.4**
Hard coal[c,d]	**2.4**	**1.9**	**2.2**	**2.4**	**2.4**	**2.3**
Natural gas[c,d]	**5.6**	**4.5**	**6.0**	**6.7**	**7.1**	**7.4**
	Cost assumptions for lignite production, 2019-2040					
Total of short-term-variable costs, unavoidable costs and long-term costs[d]	**6.4**	**6.4**	**6.4**	**6.4**	**6.4**	**6.4**
	Prices for ETS certificates, with regard to prices of the year 2016 (€/EUA), 2019-2040					
2021 Projections Report[e]	**24.1**	**22.9**	**25.0**	**30.0**	**40.0**	**53.0**
Sensitivity 1, 2021 Projections Report[e]	**24.1**	**22.9**	**34.0**	**44.5**	**54.0**	**65.0**
Sensitivity 2, 2021 Projection Report[e]	**24.1**	**22.9**	**49.9**	**60.6**	**71.3**	**82.0**
	Assumptions regarding the development of average end-consumer electricity prices, by sector [Eurocent 2016 / kWh]					
Households (including VAT)[f]	28.9	29.0	30.9	29.0	26.9	27.9
Commercial / institutional (trade, commerce, services) (not including VAT)[f]	21.3	20.9	20.8	19.8	17.9	18.7
Industry (not including VAT)[f]	10.6	10.7	11.8	12.0	11.2	12.6

a Source: (Statistisches Bundesamt (Destatis) 2019), (Bundesregierung 2017, 2019b), (European Commission 2020)

b Source: Own calculations on the basis of the sources given above

c The prices for 2019 are ICE market prices for crude oil and hard coal, and border-crossing prices for natural gas, pursuant to the Federal Office for Economic Affairs and Export Control (BAFA).

All prices are border-crossing prices / northwest European wholesale prices in $€_{2016}$/GJ, oriented to net calorific value.

d Source: Öko-Institut

e Sources: European Energy Exchange (EEX), Öko-Institut

f Sources: Own calculations, based on Bundesministerium für Wirtschaft und Energie (BMWi) (2018), BMWi (2016), Bundesverband der Energie- und Wasserwirtschaft e.V. (BDEW) (2016), Bundesnetzagentur (2015), Öko-Institut (2015)

5.2.2.1 Population trends

For the 2021 Projections Report, we have followed the guidelines of the European Commission. As to sensitivity, we have used the Federal Statistical Office's Variant G2-L2-W3, with high net migration. Such sensitivity is consistent with the sensitivity of the GDP (higher GDP growth rates in the years 2022-2024, and higher population figures).

5.2.2.2 Economic growth

For the 2021 Projections Report, the growth rates given in the federal government's 2020 fall projection are assumed for the years 2020 through 2025. For the period as of 2026, it is assumed that growth rates decrease slightly. For the period as of 2030, growth rates are assumed to be in keeping with those given by the European Commission (2020) for spring 2020. With regard to sensitivity, the growth rates given by the European Commission for the period as of 2020 are used.

5.2.2.3 Energy prices (crude oil, natural gas and hard coal)

With regard to the developments of recent years (and to the analyses for natural gas and hard coal described below), for modelling purposes the most-recent international projection at the time the framework data are specified has been used – that of the World Energy Outlook (WEO) 2020, for development of prices for the Brent Crude oil marker. The natural gas price trends on which the modelling is bases are developed on the basis of the WEO 2020. Taking account of the typical U.S. market / Henry Hub price differentials, the Annual Energy Outlook (AEO) 2020 projection can be used to derive similar price levels and trends. For hard coal, price projections of the WEO 2020 are used as a basis.

For the modelling, the prices for crude oil, natural gas and hard coal as shown in Table 12 are used as a basis. To take proper account of the special situation prevailing in the year 2020, the price levels for 2025 are determined as an average of the basic values for 2019 and 2030.

5.2.2.4 Cost assumptions pertaining to lignite production

For the 2021 Projections Report, total marginal costs for lignite production of 6.4 €$_{2016}$/MWh$_{th}$ are used as the starting point. In any assessment of future cost-effectiveness in the lignite mining sector, the cost shares that are assumed for fixed costs, and for long-term investments, play a decisive role. A reliable breakdown of total costs is obtained with the following benchmarks:

- Short-term variable costs: Energy costs for open-pit-min operations, and other variable cost components; 1.55 €$_{2016}$/MWh$_{th}$ in keeping with EWI et al. (2014). These costs are incurred in proportion to lignite production.
- Long-term operational costs for open-pit mining: Personnel, insurance, service and maintenance, movement of conveyer bridges, conveyer belts and excavators, etc. In keeping with EWI et al. (2014), these also contribute 1.55 €$_{2016}$/MWh$_{th}$. It is assumed that these costs can be reduced as demand decreases.
- Investment costs: Land purchases, compensation, drainage systems and their operation, conveyer bridges, bucket wheel excavators, spreaders, mining damage, recultivation, etc. The remaining amount of 3.3 €$_{2016}$/MWh$_{th}$ is assigned to this item. Once an open-pit mine is developed, these costs cannot be avoided in the long term.

With regard to power plant operations as seen in the PowerFlex dispatch model, only variable costs are relevant; they are equivalent to the marginal costs for fuel procurement. The other types of costs do not have to be taken into account in connection with decisions on power-plant operations, but they do have to be considered in connection with new construction of power plants and with decommissioning of power plants.[143]

In general, it is assumed that the inflation-adjusted costs of lignite production will remain constant in future. In the context of the legally mandated phase-out of lignite-based electricity generation, by no later than 2038, it is also assumed that no more significant or avoidable investments will be made. As a result, the cost structures will remain constant until lignite-based electricity generation is terminated in Germany.

5.2.2.5 Prices for ETS certificates

Agreement between actual fuel prices and assumed fuel prices plays a significant role in light of the electricity sector's great importance with regard to emissions trends – and to the development of prices within the EU ETS. For this reason, the fuel-price assumptions were used as a basis for studying typical fuel-change constellations in the continental European electricity market and deriving benchmarks for fuel-change costs that agree relatively well with the price trends observed in the market, and with the European Commission's recent modelling – and that therefore can be used for the year 2025, in a departure from the Commission's recommendations. For the basis years as of 2030, the Commission's recommendations were adopted.

5.2.2.6 Development of CO_2 prices for heat and transport (BEHG prices)

The development of the CO_2 prices for heat and transport, pursuant to the Fuel Emissions Trading Act (BEHG), is described in Chapter 4.5.1.2.

5.2.2.7 Development of mean end-consumer electricity prices

The development of the mean end-consumer electricity prices is shown in Table 12. The prices shown reflect assumptions regarding the development of wholesale prices, taxes and levies. The slight, continuous increase through 2025 is due to increasing network charges and wholesale prices. The decrease after 2025 is due primarily to the forecast decreases in the EEG levy. For the years 2021 and 2022, the agreed caps on the regular EEG levy, 6.5 and 6 ct/kWh, have been taken into account. For the years after 2022, the fact that the EEG levy is offset with funding from the national emission trading system (nEHS) has been taken into account. The household prices for 2020 are based on values from statistics, while for industry only end-consumer prices through 2018 are available. The prices for companies in the commercial and institutional sector (trade, commerce and services) were derived from the relevant individual price components, most of which are available for the year 2020.

[143] Öko-Institut (2017): Hermann, H.; Greiner, B.; Matthes, F. C.; Cook, V. Die deutsche Braunkohlenwirtschaft, Historische Entwicklungen, Ressourcen, Technik, wirtschaftliche Strukturen und Umweltauswirkungen. Studie im Auftrag von Agora Energiewende und der European Climate Foundation. Öko-Institut. Berlin, Mai 2017. Available online at https://www.agora-energiewende.de/fileadmin2/Projekte/2017/Deutsche_Braunkohlenwirtschaft/Agora_Die-deutsche-Braunkohlenwirtschaft_WEB.pdf, last checked on 11 Jan. 2021.

5.2.3 Inclusion of the coronavirus pandemic in the projections

Reporting for the year 2020 faces two types of challenges. Comparisons of the emissions trends for 2020 with those of previous years are of limited value, since the coronavirus pandemic led to a sharp economic downturn and to a decline in demand for transport services. For this reason, the GHG emissions picture of 2020 is considerably different from the pictures of other years. In addition, the economic downturn of 2020 also has an impact on the GHG emissions projected for subsequent years.

Furthermore, modelling for the Projections Report began in the fourth quarter of 2020, and was completed toward the end of the first quarter of 2021 – i.e., prior to greenhouse-gas reporting for the year 2020. In the main, the impacts of the coronavirus pandemic were taken into account in two ways. Firstly, key framework data reflect the effects of the pandemic. The assumptions regarding the economy, for example, include a sharp downturn in 2020 and a rapid recovery in 2021. Economic trends affect gross value added, and that also experience a downturn in 2020 (Chapter 5.2.2.2). Via linkage between the models (Chapter 5.2.1), effects in other sectors occur as well. Lower gross value added, for example, leads to lower electricity demand on the part of industry. That, in turn, affects power-plants emissions in the energy and industry sectors. Secondly, an economic stimulus programme was launched, in summer 2020, in order to ease the coronavirus pandemic's economic impacts. That programme's measures have been taken into account in the modelling, and thus they affect the projected GHG emissions. As a result of the aforementioned challenges, the present report uses the German Environment Agency's estimate of previous-year German GHG emissions, which was published on 15 March 2022, as its source for 2020 GHG emissions data in the sectors energy industry, industry, buildings, transport and waste management. Such previous-year estimates take account of all statistical data available through the end of February of the year in which the estimate is carried out. Along with data on primary energy consumption, they also consider data such production figures and meteorological data. In addition, the estimation process includes surveys of experts. Information about the data sources and methods used, in the various source categories, is provided in Umweltbundesamt (UBA) (2020). In cases in which the previous-year estimate for 2020 has been applied, a note of this is made below relevant tables.

5.2.4 Sensitivities

As a result of the long-term perspective used – through the year 2040 – in assumptions pertaining to population growth, economic trends and CO_2 prices, the assumed framework data are subject to uncertainties. Sensitivity analyses have been carried out in order to assess divergences from the assumptions chosen. Such analyses are carried out by successively modifying the basic assumptions being used and then determining the impacts of such modification. The following parameters are modified in sensitivity analyses:

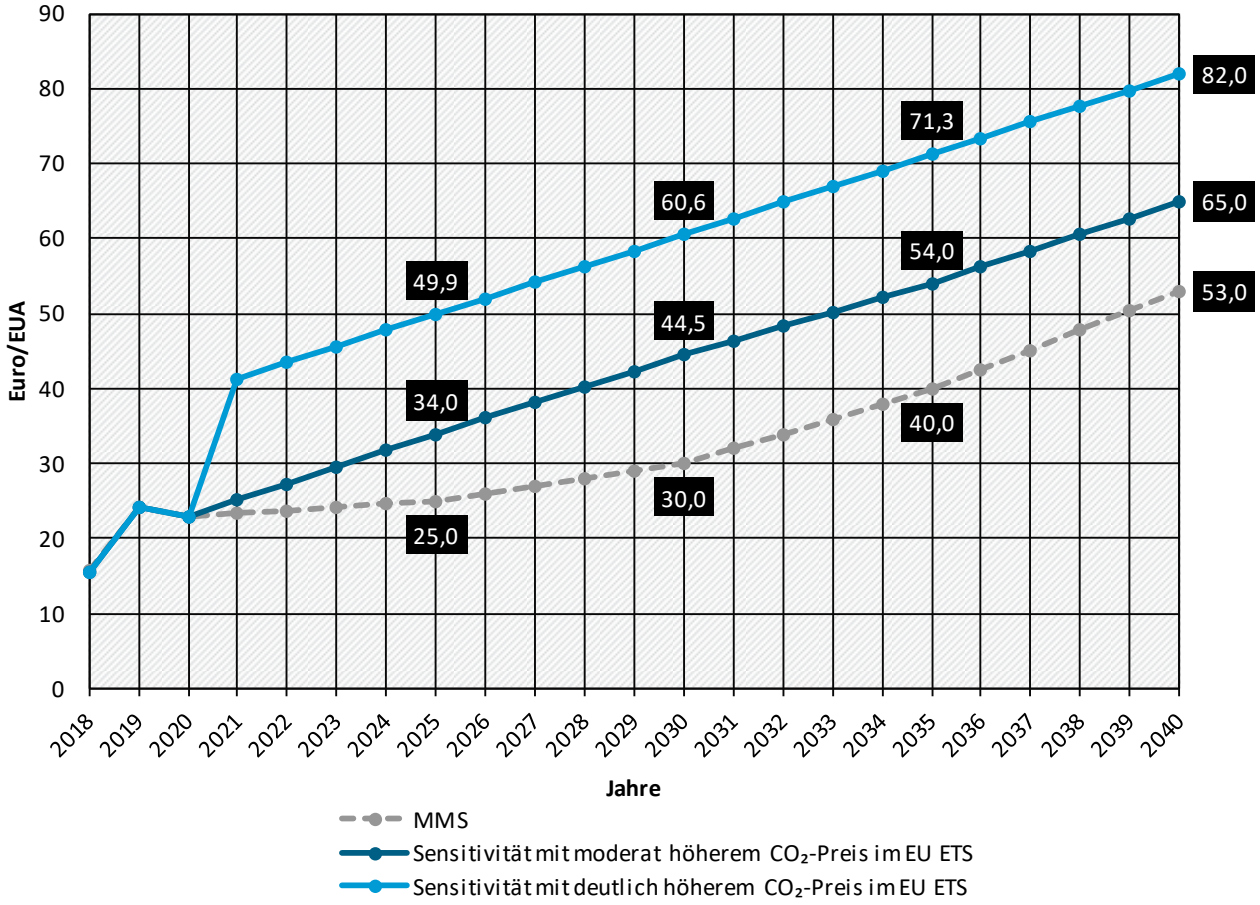
- Economic growth;
- Population trends;
- Prices for EUA European Allowances;
- BEHG prices.

As to assumptions regarding economic growth, the sensitivity analyses use the European Commission's economic forecast. It takes account of the 2020 coronavirus pandemic by assuming a sharp economic downturn, followed by a rapid recovery.

The sensitivity calculation with regard to population growth assumes a population increase resulting from significant immigration. The impacts of these two factors on energy-related GHG emissions were studied with the help of component analysis. In each of two sensitivity calculations regarding CO_2 prices, a higher price pathway for EUA European Allowances was assumed (Source: Assumptions of Öko-Institut

Figure 27). Also, additional electricity-market models were used for both CO_2-price scenarios.

Finally, for determination of the sensitivity of the BEHG prices, values from the National Energy and Climate Plan were used, which increase more rapidly in the with-measures scenario than the BEHG prices used.



Source: Assumptions of Öko-Institut

Figure 27: Alternative price pathways for EUA European Allowances, in sensitivity analysis[144]

Table 13 presents a summary of GHG emissions development in the sensitivity calculations. It emerges that the modified basic assumptions in the with-measures scenario have only slight impacts, and that the emissions-reduction target of -55 % or 65 % by the year 2030, with respect to 1990, is not achieved.

[144] translation: x-axis = years; categories = MMS = With-measures scenario, Sensitivity with moderately higher CO2 price in the EU ETS, Sensitivity with significantly higher CO2 price in the EU ETS

Table 13: Development of GHG emissions in the sensitivity calculations (WMS)

	1990	2018	2025	2030	2035	2040
			Mt CO2e			
			Emissions in the energy sector (including international aviation)			
With-measures scenario	1,049.2	750.6	659.7	556.2	441.6	339.1
Economic growth pursuant to European Commission			658.4	551.7	438.1	336.4
Larger population			663.4	559.6	444.7	342.0
Moderately higher EUA prices			654.6	547.7	440.1	338.6
Considerably higher EUA prices			632.2	532.2	422.2	338.6
Higher BEHG prices			659.6	552.1	432.9	329.3
Difference with respect to the WMS:						
Economic growth pursuant to European Commission			-1.2	-4.4	-3.5	-2.7
Larger population			3.7	3.5	3.0	2.9
Moderately higher EUA prices			-5.0	-8.5	-1.6	-0.5
Considerably higher EUA prices			-27.5	-24.0	-19.5	-0.6
Higher BEHG prices			-0.1	-4.1	-8.8	-9.8
Total emissions (not including international transport & LULUCF):						
With-measures scenario	1,249.5	858.3	750.9	632.9	514.0	408.7
Economic growth pursuant to European Commission			749.7	628.4	510.5	406.0
Larger population			754.6	636.4	517.0	411.6
Moderately higher EUA prices			745.8	624.4	512.4	408.2
Considerably higher EUA prices			723.4	608.9	494.5	408.2
Higher BEHG prices			750.8	628.8	505.2	398.9
Reduction of total emissions with respect to 1990 (%):						
With-measures scenario		-31.3 %	-39.9%	-49.3%	-58.9%	-67.3%
Economic growth pursuant to European Commission			-40.0%	-49.7%	-59.1%	-67.5%
Larger population			-39.6%	-49.1%	-58.6%	-67.1%
Moderately higher EUA prices			-40.3%	-50.0%	-59.0%	-67.3%
Considerably higher EUA prices			-42.1%	-51.3%	-60.4%	-67.3%
Higher BEHG prices			-39.9%	-49.7%	-59.6%	-68.1%

Source: Calculations of Öko-Institut

6 Financial support and technology cooperation

6.1 International climate finance

6.1.1 General principles and assumptions

Commitments to climate action go hand-in-hand with commitments to development. With regard to supporting developing, emerging and transition countries in climate-change adaptation and mitigation, Germany considers the implementation of the Paris Agreement and the Agenda 2030 to be closely linked. 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. The following chapter focuses solely on Germany's commitments in this area in the years 2019 and 2020. Information regarding Germany's efforts in the area of international climate finance, and climate action and climate adaptation in developing and emerging countries in the first half of the reporting period of the 8th National Communication (2017 – 2018), is presented in the federal government's 4th. Biennial Report.[145] [146]

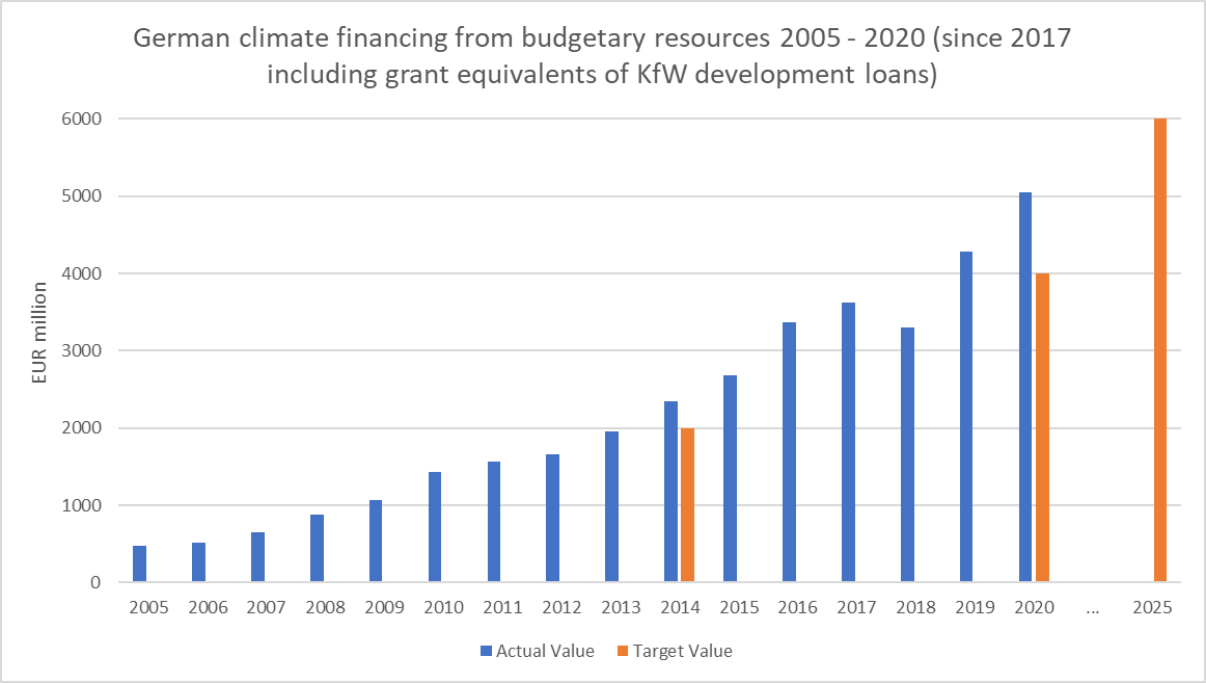
6.1.2 Overview of international climate finance, 2019–2020

The German government continues to be in favour of ambitious financial support for developing, emerging and transition countries, for reduction of GHG emissions, and adaptation to the impacts of climate change, and it works to promote a just transition in these areas. In 2019, Germany already fulfilled an intent that had been announced in May 2015, at the Petersberg Climate Dialogue, by then German Chancellor Angela Merkel, calling for Germany to double its climate financing, from two billion euro annually (in 2014) to four billion euro annually (in 2020). At the 2022 Petersberg Climate Dialogue, German Chancellor Olaf Scholz then again confirmed the commitment that former Chancellor Merkel had made at the 2021 G7 Summit in Carbis Bay, calling for increasing Germany's public-funded contribution to international climate finance to at least 6 billion euro per year by no later than 2025.

[145] Germany´s Fourth Biennial Report on Climate Change under the United Nations Framework Convention on Climate Change 2020 (unfccc.int)

[146] The relevant data for the years 2017 and 2018 are provided in CTF Tables 7, 7a and 7b, 8 and 9, which are available here: https://unfccc.int/documents/210563.

Figure 28: Germany's international climate financing from budgetary resources, 2005 – 2020 (in million euro)



Source: Own figure, Federal Ministry for Economic Cooperation and Development (BMZ).

In 2019, Germany provided budgetary resources amounting to 3.64 billion EUR / 4.08 billion USD[147] for international climate finance. Since 2017, Germany has documented and reported grant-equivalents of KfW development loans. In 2019, they amounted to 642 million EUR / 719 million USD. In 2019, in addition to the budgetary resources and grant-equivalents provided, a total of 2.47 billion EUR / 2.77 billion USD of mobilised public-sector climate financing from capital-market funds was committed, via KfW Development Bank and DEG (Deutsche Investitions- und Entwicklungsgesellschaft mbH). All in all, the public-sector climate-finance funding provided amounted to about 6.76 billion EUR / 7.57 billion USD. Also in 2019, 770 million EUR / 862 million USD worth of private climate-finance funding was mobilised, via use of public-sector funds and via KfW and DEG.

In 2020, Germany's international climate-finance funding from budgetary resources amounted to about 4.3 billion EUR / 4.91 billion USD. The volume of grant-equivalents in 2020 amounted to about 756 million EUR / 863 million USD. In addition, the public-sector climate-finance funding mobilised by KfW Development Bank and DEG amounted to about 2.55 billion EUR / 2.91 billion USD. As a result, public-sector climate-finance funding provided a total sum of about 7.6 billion EUR / 8.67 billion USD. The private climate financing mobilised via use of public-sector funding amounted to about 192 million EUR / 219 million USD in 2020.

In addition, funding in the amount of about 53 million EUR / 59 million USD was provided in 2019 to Annex I countries receiving official development assistance (ODA) – Ukraine, Turkey and Belarus. In 2020, funding for Annex I countries amounted to about 38 million EUR /

147 Conversion using OECD reference exchange rates for 2019 and 2020 (https://data.oecd.org/conversion/exchange-rates.htm). In connection with contributions to multilateral funds, the reference exchange rate for the relevant replenishment round was used, where available, as a basis (for example, for contributions to GCF or GEF).

44 million USD. These amounts are not taken into account in the aggregated climate-financing figures given in the report.

Since 2005, Germany has increased its financial contribution to climate finance, from budgetary resources, nearly tenfold. This reflects the ambitious goals being set by the departments awarding funding, as well as the success achieved in bringing climate issues into the mainstream of German development cooperation.

6.1.3 German climate-financing instruments, institutions and initiatives

In its international cooperation in the area of climate and development, the German Federal Government makes use of a broad spectrum of instruments and institutions: Bilateral financial, technical and academic cooperation: German climate finance focuses especially on bilateral cooperation. From 2019 to 2020, bilateral cooperation accounted for an average of 83 % of the budgetary resources used for climate finance (including grant-equivalents).

Multilateral cooperation: Multilateral cooperation includes contributions to international climate funds, such as the Green Climate Fund (GCF), the Climate Investment Funds (CIFs), the Adaptation Fund (AF), the Global Environment Facility (GEF), as well as cooperation with multilateral development banks (MDBs) and specialised United Nations organisations.

During the reporting period for the Biennial Report, Germany, by continuing and/or providing comprehensive support for international initiatives, has made important contributions in support of rapid, ambitious implementation of the Paris Agreement. Noteworthy among these efforts are the successful Nationally Determined Contributions Partnership (NDCP) (see section 6.1.3.2), and the “InsuResilience Global Partnership,” a G20-V20 Initiative for establishment of solutions for climate and disaster risk finance and insurance (see section 6.1.5.2). In addition, during the recovery period following the coronavirus pandemic, Germany is working toward a “Green Recovery,” a sustainable recovery effort.

6.1.3.1 Methodology used to measure German climate finance

Germany attaches great importance to measuring and communicating its climate finance transparently and comprehensively. For this reason, Germany is reporting bilateral climate finance (in Table 7b) on a project-specific basis aimed at describing the individual projects in as much detail as possible. Also, supplementary information about the individual projects involved is provided on the websites of the responsible ministries, BMZ[148], BMUV[149], BMWK[150], AA and BMBF[151]. The projects of the International Climate Initiative (ICI), which are being implemented since 2022 by the Federal Ministry for Economic Affairs and Climate Action (BMWK), in close cooperation with the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the Federal Foreign Office (AA), are presented on a joint ICI website[152].

The climate-finance funding as calculated comprises the new commitments made, and the resources disbursed, in the reporting year. All newly committed funding and disbursed

[148] https://www.bmz.de/en/development-policy/climate-change-and-development/climate-financing.
[149] This ministry was formerly called the “BMU.” In the report, its current designation, “BMUV,” is used, regardless of the time at which initiatives take place.
[150] This ministry was formerly called the “BMWi.” In the report, its current designation, “BMWK,” is used, regardless of the time at which initiatives take place
[151] https://www.fona.de/en/.
[152] https://www.international-climate-initiative.com/en/search-project/.

funding in the reporting year falls within the category “new and additional.” As a result, all of the climate-finance funding reported in tables 7, 7a and 7b is “new and additional.”

Since 2013, Germany has reported on all of its public-sector climate-finance efforts, including mobilised public-sector climate-finance funding. Since 2015, mobilised public-sector climate-finance funding is reported on a by-project basis.

Germany distinguishes between three sub-categories of climate finance:

a) **Climate finance from budgetary sources, including grant-equivalents of KfW development loans:** Climate finance provided from the public budget is recorded in this category. Since reporting year 2017, grant-equivalents of development loans are also documented and reported. The term “grant-equivalent” refers to the difference between the nominal value of a loan and the cash value of the pertinent debt service (repayment and interest payments, discounted with the discount rates defined by the Development Assistance Committee (DAC) of the Organisation for Economic Co-operation and Development (OECD)). A grant-equivalent is thus a calculatory value used in quantifying the value of a discount on a concessionary loan. To prevent double-crediting, grant-equivalents are deducted from foreign loans among KfW’s development loans (see category b). Since the interest subsidies coming from budgetary resources used to leverage KfW development loans are given in aggregated form, per region[153], the subsidies are deducted from the grant-equivalents. In addition, since reporting year 2014 multilateral contributions to the Climate Fund and MBDs are measured with the Imputed Climate Relevant Contributions approach in keeping with the methods developed by the OECD “Joint ENVIRONET and WP-STAT Task Team to Improve Rio Markers, Environment and Development Finance Statistics” (JTT).

b) **Mobilised public financing** is climate-related loan financing from KfW Development Bank and DEG. It predominantly comprises finance streams that count as official development assistance (ODA), as a rule in the form of

   concessional loans.

c) **Private climate finance mobilised through public-sector funding:** In 2019 and 2020, the private climate-finance resources mobilised by the federal government consisted especially of revolving lines of credit granted to local (development) banks; holdings of structured funds; and public-private partnerships.

Germany reports mobilised private climate-finance resources for the areas and financing instruments for which agreed OECD reporting methods are available. Both DEG and KfW Development Bank use such methods in calculating mobilised private financing.

For transparent determination of climate-finance levels, and since reporting year 2011, Germany uses the OECD Rio markers system. In use of the Rio-marking procedure, the areas of climate change mitigation and climate change adaptation are differentiated. Also, additional information must be provided as to whether climate change mitigation or climate change adaptation is a principal objective (RM score of 2) or a significant objective (RM score of 1) of the measure. If a project has a score of 1, 40 % of the project budget is credited; if it has a score of 2, 100 % is credited. Budgets of projects that are “cross-cutting” in that they target both climate change mitigation or climate change adaptation, as either a

[153] Combined in a manner similar to that used for the funding regions for the BMZ’s bilateral cooperation in Asia, southeast Europe / Caucasus, Latin America and the Caribbean, Near East and Africa.

significant objective or a principal objective, are also credited at a level of 100 %. To prevent double-counting, in applying the Rio-marker system to its projects, Germany uses the "sum rule" whereby the sum total of a project's Rio-marker scores may not exceed 2.

The federal government's bilateral cooperation projects almost always include technology-transfer and capacity-development components, and they often apply a cross-cutting approach. To date, no official markers for capacity development and technology transfer have been defined. Consequently, such aspects of measures cannot be separately listed. Sample projects with a special focus on technology transfer and capacity development are shown in CTF Tables 8 and 9.

The statistical information given in the attached CTF Tables 7, 7a and 7b include, for all climate-relevant bilateral-cooperation projects, the public-budget funding that was committed in the relevant year, or that, in the case of funding provided from the Energy and Climate Fund / International Fund for Climate and Environmental Protection, was disbursed. Multilateral contributions to climate finance were taken into account in the form of disbursements. Mobilised public financing, i.e., climate-related loan financing from KfW Development Bank and DEG, is also reported as financing commitments.

6.1.3.2 Support for Nationally Determined Contributions and the NDC Partnerships

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. In recent commitments in Germany's climate-related development cooperation, NDCs were a central reference point.

In order to quickly and effectively commence the implementation of the NDCs and contribute to raising climate ambition, BMZ and BMUV, in conjunction with the Moroccan COP Presidency, other industrialised countries and developing countries and various international organisations, launched a global

partnership to promote the implementation of NDCs at the beginning of 2016 (the NDC Partnership or NDCP).[154] 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. The NDC Partnership is in principle open to all countries and international organisations that support its objectives and principles.[155]

Until the end of 2018, in the start-up phase of the Partnership, Germany and Morocco were Co-Chairs of the Steering Committee. In the framework of COP24, they passed these roles on to the Netherlands and Costa Rica, who then served as Co-Chairs until the end of 2020. After handing over its Co-Chairmanship, Germany has continued to serve as a member of the Steering Committee. This multilateral partnership continues to develop in a very dynamic way: To date, a total of 112 countries, 42 international organisations and development banks, and 33 associated members have jointed the partnership.[156]

[154] https://ndcpartnership.org/

[155] These include: 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, promote gender equality.

[156] http://www.ndcpartnership.org/members - Stand August 2022

In the reporting period, in-country implementation in the framework of the NDC Partnership[157] has begun in 75 member-countries and in three regional initiatives. The aim of these efforts is to prepare national partnership plans that organise NDC priority activities, and match them with NDC Partnership member support and in-country stakeholders. The plans and their preparation provide an opportunity for improving a) cooperation between in-country stakeholders, for prioritisation of national climate goals, and b) coordination of donors. As of the end of 2020, such partnership plans, which operationalise NDC implementation and address priority requirements of partners, had been prepared in a total of 30 countries.

Since 2019, donors and implementation organisations, working via the NDC Partnership's *Climate Action Enhancement Package* (CAEP), have supported 67 countries in revising their climate goals and making them more ambitious. Such support is provided either directly by the Partnership's members or via a central *Technical Assistance Fund* (TAF). Germany directly supports the CAEP, in a total of 26 countries, via various implementing organisations, and it has paid more than 12 million EUR / 13.7 million USD into the TAF.

In June 2020, the NDCP launched the *Economic Advisory Initiative*, which is aimed at supporting sustainable, climate-friendly recovery and rebuilding in the wake of the coronavirus pandemic. The Initiative provides for the rapid employment of *embedded economic advisors*, charged with supporting preparation of climate-friendly, sustainably oriented economic stimulus packages, in finance and planning ministries in 34 member-countries. Germany is supporting the employment of such advisors in a total of 26 countries.

In order to provide organisational support for the Partnership, Germany, in cooperation with other donor countries, is financing a secretariat for the NDC Partnership – the *Support Unit*. As of the end of 2020, Germany had provided financing totalling 12 million EUR / 13.7 million USD for that purpose. In addition to orienting its International Climate Initiative (ICI) and climate-relevant bilateral development cooperation to the NDC Partnership Plans, the federal government has provided financing contributions in direct support of the Partnership. The Federal Ministry for Economic Cooperation and Development (BMZ) is providing a total of 107 million EUR / 128 million USD to the World Bank, GIZ, WRI, UNDP and WWF, in order to deliver rapid, flexible technical support, at the country level, in the NDCP context. In the reporting period, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) provided 96 million EUR / 113 million USD, via a consortium of eleven implementing organisations with a diverse range of expertise, aimed at the NDC Partnership.

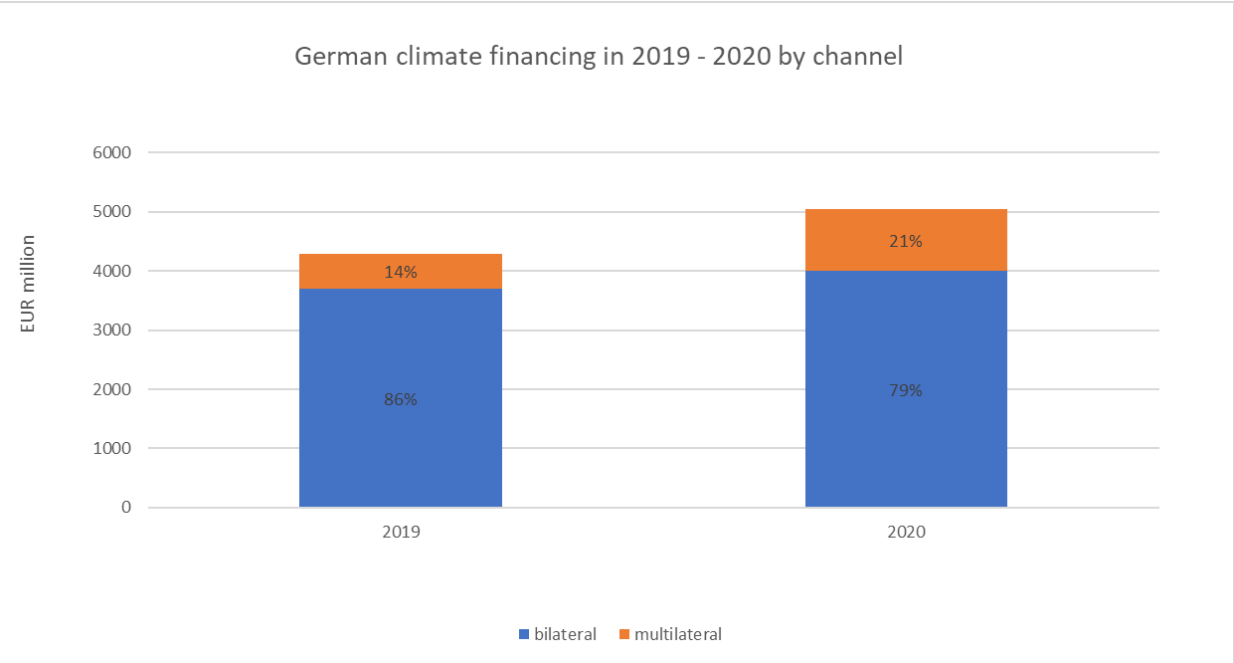
6.1.4 Channels for delivering German international climate finance

Germany provides a large share of its climate-finance contributions – about 83 %, with respect to the years 2019 and 2020 – in the form of bilateral cooperation (cf. Figure 29). Germany's commitments in this area build on partner countries' efforts to integrate climate change mitigation and climate change adaptation within their national development strategies. In 2019, in this context, bilateral climate finance (including 642 million EUR / 719 million USD of grant-equivalents) accounted for a total of 3.7 billion EUR / 4.14 billion USD, while multilateral climate finance accounted for 588 million EUR / 658 million USD. In 2020 overall, a total of nearly 4 billion EUR / 4.56 billion USD (including grant-equivalents

[157] Information about the NDCP's country process and its Country Engagement Strategy: https://ndcpartnership.org/country-engagement

amounting to 756 million EUR / 863 million USD) flowed to bilateral climate finance, and 1.06 billion EUR / 1.21 billion USD flowed to multilateral climate finance.

Figure 29: German climate finance contributions, in the years 2019 – 2020, from budgetary resources and grant-equivalents, broken down by bilateral and multilateral (in millions of € and percent)

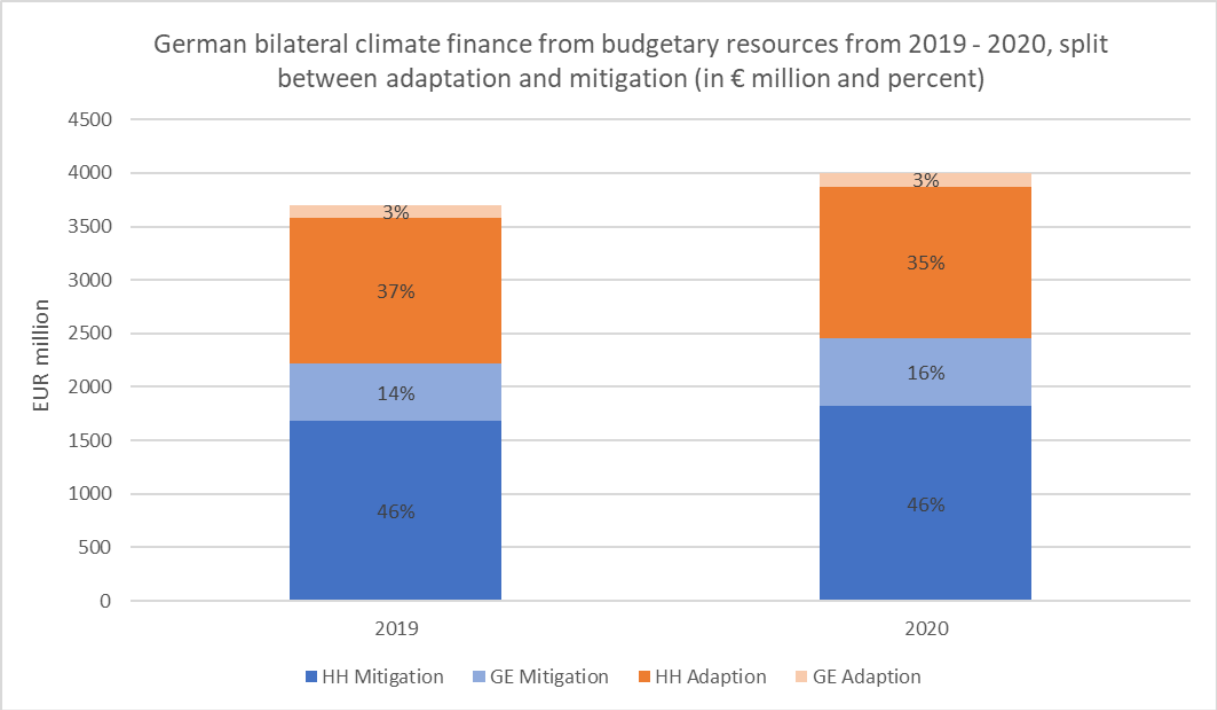


Source: Own figure, Federal Ministry for Economic Cooperation and Development (BMZ).

6.1.4.1 Bilateral cooperation

The federal government aims to achieve a suitable balance between its bilateral climate finance for emissions-reduction projects and its bilateral finance for adaptation to climate change (Figure 30). In 2019, about 1.48 billion EUR / 1.66 billion USD worth of budgetary resources, including grant-equivalents, were invested in adaptation measures, and about 2.22 billion EUR / 2.48 billion USD were invested in emissions-reduction measures. In 2020, 1.54 billion EUR / 1.76 billion USD of the funding provided from the federal budget, on a bilateral basis, flowed to adaptation projects, and 2.46 billion EUR / 2.81 billion USD went to emissions-reduction projects. As a result, in the 2019 – 2020 reporting period, an average of 40 % of Germany's bilateral climate finance went toward adaptation projects.

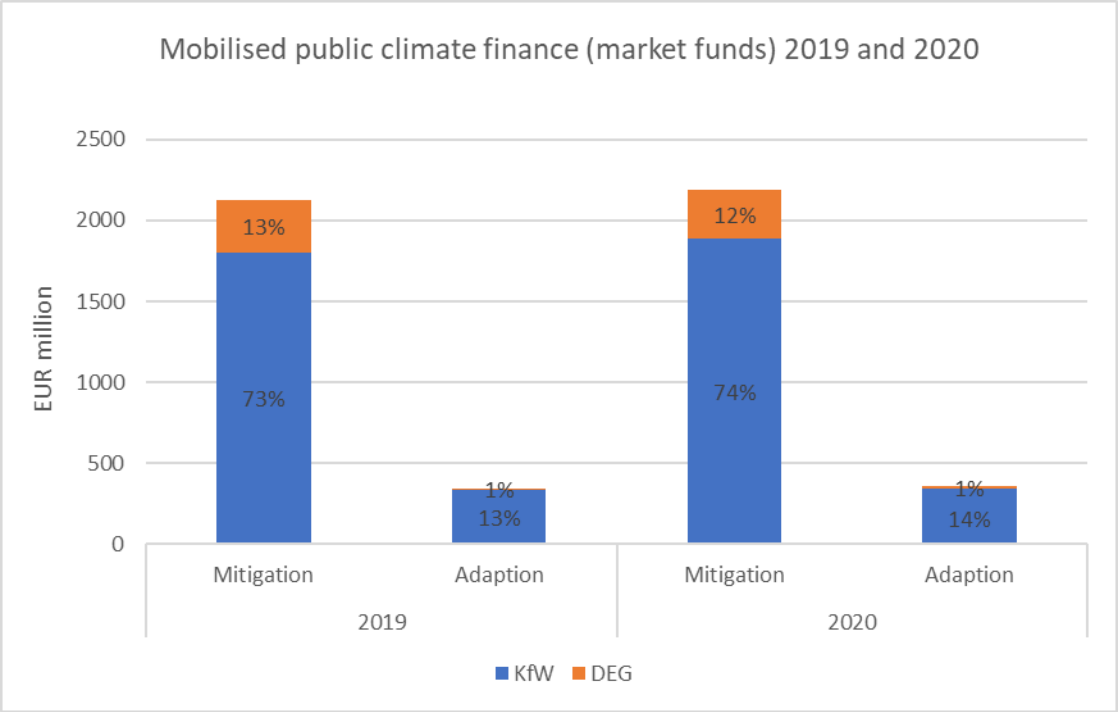
Figure 30: German bilateral climate finance from budgetary resources, 2019–2020, broken down by the categories "mitigation" and "adaptation" (in millions of € and percent)



Source: Own figure, Federal Ministry for Economic Cooperation and Development (BMZ).

Since 2013, in addition to reporting on its climate financing from public-sector budgetary resources, Germany has also reported on publicly mobilised climate finance, i.e. on climate-relevant loan financing provided by KfW Development Bank and DEG, with the help of market resources. As shown in Figure 29, in 2019 – and in addition to the budgetary resources provided – an additional total of 2.47 billion EUR / 2.77 billion USD were committed by KfW Development Bank and DEG, from capital-market funds, for mitigation and adaptation measures. In 2020, the public-sector funding mobilised via KfW Development Bank and DEG amounted to 2.55 billion EUR / 2.91 billion USD.

Figure 31: German financing, as drawn from mobilised public-sector market funding, 2019 and 2020 (in percent and millions of €)

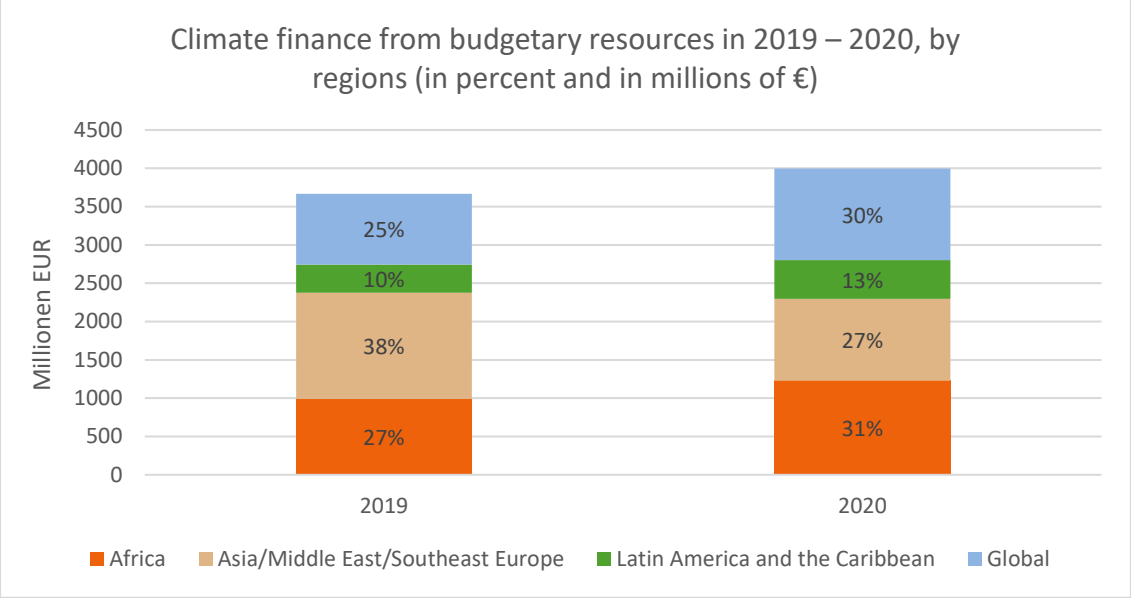


Source: Own figure, Federal Ministry for Economic Cooperation and Development (BMZ)

Differentiated by regions, the 3.7 billion EUR / 4.14 billion USD of total bilateral climate finance (budgetary resources including grant-equivalents) breaks down as follows in 2019: Germany provided support as follows: 991 million EUR / 1.11 billion USD to partner governments in Africa; 1.38 billion EUR / 1.55 billion USD to partner governments in the Asian, Middle Eastern and Southeast European region: 370 million EUR / 415 million USD to partner governments in Latin America and the Caribbean; and 953 million EUR / 1.07 billion USD via global projects (cf. Figure 32).

Of the some 4 billion EUR / 4.56 billion USD of bilateral climate finance (budgetary resources including grant-equivalents) it provided in 2020, Germany expended 1.23 billion EUR / 1.4 billion USD on cooperation with African partner governments; 1.07 billion EUR / 1.22 billion USD on cooperation with partner governments in the Asian, Middle Eastern and Southeast European region; 504 million EUR / 576 million USD on cooperation with partner governments in Latin America and the Caribbean; and 1.2 billion EUR / 1.36 billion USD on global projects (cf. also Figure 32).

Figure 32: Climate finance from budgetary resources in 2019 – 2020, by regions (in percent and in millions of €)



Source: Own figure, Federal Ministry for Economic Cooperation and Development (BMZ)

6.1.4.2 Multilateral cooperation

Germany provides part of its climate financing through multilateral institutions, in the form of contributions to international climate funds and multilateral organisations. In addition to being involved as a donor, Germany also supports funds and multilateral development

banks with regard to their strategic orientation and operational implementation of their portfolios, with a view to optimising their contribution to efficient, effective climate finance.

The funds that were directly set up under the United Nations Framework Convention on Climate Change (and that now operate under the Paris Agreement) 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. These include, for example, the Climate Investment Funds (CIF), the Global Risk Financing Facility and the Sustainable Energy Fund for Africa. 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); and the Asian Development Fund (AsDF).

These contributions, as well as its contributions to the GEF, are included in German climate finance in accordance with the imputed climate-relevant shares determined by these institutions. In addition, Germany provides annual contributions and special initiatives in support of United Nations programmes for implementation of the global climate agenda.

For the first replenishment of the GCF, Germany has doubled its original contribution, to 1.5 billion EUR / 1.69 billion USD. In the now-completed phase, Germany was already one of the largest donors to the fund, with a commitment in the amount of 750 million EUR / 1.003

billion USD. 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.

With a commitment in the amount of 420 million EUR / 496 million USD for the 7th replenishment period, 2018 – 2022, Germany was the second-largest GEF donor after Japan. Ever since the GEF began publishing Germany's imputed climate relevant share (2015), Germany has used it as a basis for calculating the GEF climate contribution. Germany serves as a member of the GEF Council. In the framework of that body, it works for harnessing of synergies between the various funds in the GEF and for expansion of high-quality monitoring of project and programme impacts. Once again, in the 8th GEF replenishment phase (2022-26), Germany is a key donor.

As of the end of 2020, the German commitments to the LDCF amounted to a total of 315 million EUR / 372 million USD (as of September 2020). In the reporting period, Germany paid some 50 million EUR / 56.5 million USD into the Fund. This makes Germany the largest donor to the LDCF. In addition, Germany provides technical advisory services on LDCF priorities – for example, on innovative approaches in climate risk management, and on access for Least Developed Countries (LDCs). It also advises the Fund on concepts for 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.

In total, Germany's commitments to the SCCF amount to 90 million EUR / 120 million USD (as of September 2020). This makes Germany the largest donor to the SCCF. In the reporting period, Germany did not make any further contributions to the Fund. In general, Germany concentrates its support for the SCCF on adaptation to climate change, and it advises the Fund with regard to the design of project proposals.

In 2019 and 2020, Germany paid a total of 80 million EUR / 91 million USD into the AF. With these contributions, it supports adaptation projects around the world. In addition, Germany serves as a member of the Board, which is located in Bonn. Through its active participation on the Board, Germany supports the strategic orientation and the operational implementation of the Fund.

As of the end of 2020, Germany's contribution to the CIFs amounted to 630 million EUR / 719 million USD. With its contribution to the Clean Technology Fund (CTF), in the amount of 500 million EUR / 615 million USD, in the form of a loan, Germany is the fourth-largest donor to the CTF. Furthermore, Germany supported the Pilot Program for Climate Resilience (PPCR) with a grant of 50 million EUR / 66 million USD, and the Global Energy Storage Programme (GESP) with a grant of 80 million EUR / 97 million USD. In addition to providing financial contributions, Germany also participated actively in the work of the CIFs.

The total commitments to the Multilateral Fund for the Implementation of the Montreal Protocol (MP), since 1991, amounted to 4.19 billion USD (as of October 2020). Of that amount, Germany contributed about 446 million USD. Germany's contribution in the years 2019 – 2020 amounted to 24.4 million EUR / 27.6 million USD.

6.1.4.3 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. Germany participates in the following funds of multilateral development banks (MDBs) through its regular core funding contributions: IDA, AfDF, AsDF.

These contributions are included in German climate finance in accordance with the imputed climate-relevant shares determined by these institutions.

In addition, Germany promotes close cooperation with institutions in multilateral initiatives and partnerships, such as the Global Risk Financing Facility and above-mentioned NDC Partnership. In the executive bodies, Germany actively supports climate-related topics, and it clearly advocates a climate-oriented agenda and a strong, comprehensive Paris Alignment on the part of the MDBs.

A list of all of Germany's payments into climate funds, multilateral development banks and climate-specific trust funds is presented in CTF Table 7a.

6.1.4.4 Specialised UN organisations

Germany also pays annually into designated United Nations programmes in order to boost expertise and develop capacities in selected areas. A list of the UN programmes it supports is provided in Tables 7a and 7b.

Germany also provides funding for initiatives, fiduciary funds and knowledge centres. Its support in these areas amounted to a total of 23.7 million EUR / 26.6 million USD in 2019, and of 74.2 million EUR / 84.7 million USD in 2020.[158] Through these initiatives, Germany strengthens capacity building in developing countries relative to the implementation of climate change mitigation and adaptation measures; increased climate transparency; and measures for implementing the Montreal Protocol. In addition, it annually supports a) the activities of the UNFCCC secretariat and b) climate-related knowledge generation in several institutions. In the period 2019 – 2020, Germany provided the UNFCCC secretariat with 12.6 million EUR / 14.2 million USD in support (compulsory and voluntary contributions).

In addition, Germany makes voluntary contributions to the trust fund of the Intergovernmental Panel on Climate Change (IPCC), and it provided the Technical Support Unit of the IPCC's Working Group II with support totalling about 10.7 million EUR / 12.6 million USD in the current reporting cycle (2016 – 2022).

6.1.5 Approaches for adaptation to climate change

Climate change is already generating significant costs[159], and it is endangering success achieved to date in the area of development assistance – in areas such as poverty alleviation, drinking water supplies and infrastructure. As a result, Germany attaches great importance to supporting developing countries in adapting to climate change. Germany sees such support 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 is striving to improve climate change protection for the world's poorest and most-

[158] Of the 23.7 million EUR / 26.6 million USD provided in 2019, 15 million EUR / 16.8 million USD went to the NDC Support Unit, 7.8 million EUR / 8.7 million USD went to the International Fund for Agricultural Development (IFAD), 0.8 million EUR / 0.9 million USD went to the International Renewable Energy Agency (IRENA) and 0.1 million EUR / 0.11 million USD went to the Technology Executive Committee (TEC). In 2020, support of 57.1 million EUR / 65.2 million USD was provided to the Central African Forest Initiative (CAFI), and 8 million EUR / 9.1 million USD was provided to the Partnership on Inclusive Insurance, Risk Financing, and Sustainable Development (IDF). In the same year, IFAD and IRENA received contributions of 8.2 million EUR / 9.3 million USD and 0.9 million EUR / 1 million USD, respectively.

[159] The 5th IPCC Synthesis Report estimates that developing countries' annual costs for adaptation measures will reach 70-100 billion USD globally by 2050. The UNEP Adaptation Gap Report puts the costs at double to three times that figure.

vulnerable population groups; to prevent losses and damages from climate change; and to support households, companies and other countries in managing damages that have occurred. The German government strives to strike a suitable balance between its support for climate change mitigation and its support for climate change adaptation. In recent years, Germany's support for financing of adaptation has increased continually. In 2019, its bilateral climate finance from budgetary resources, including grant-equivalents, for adaptation to climate change amounted to 1.47 billion EUR / 1.64 billion USD. In 2020, its bilateral financing for adaptation to climate change reached a total of 1.54 billion EUR / 1.76 billion USD. Germany provides targeted support to the most vulnerable countries in the group of least developed countries (LCDs) and small island developing states (SIDS); it strengthens their adaptive capacities and increases the resilience of their agricultural production and infrastructure. In 2019, via activities funded by the Federal Ministry for Economic Cooperation and Development (BMZ) in the area of bilateral technical cooperation, about 8.4 million people received direct support in dealing with the impacts of climate change. These adaptation projects reached at least 2.5 million women. Also, in the same period, the adaptation capacities of nearly 2,00 key actors in partner countries were reinforced. In 2020, via bilateral technical cooperation, the BMZ supported 6 million people in addressing the impacts of climate change. In addition, it reached at least 2.7 million women via adaptation projects, and it reinforced the capacities of nearly 3,200 key actors in partner countries.

The priority areas of the German government's support are ecosystem-based adaptation (EbA); adaptation of agricultural production; food security; water management and adaptation; and risk management instruments in connection with climate change impacts. The support is provided via instruments such as innovative insurance solutions and adaptive social security systems, and via 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) of the BMUV – and, in future, also of the Federal Ministry for Economic Affairs and Climate Action (BMWK) and of the Federal Foreign Office (AA) – is also an important component of German climate finance for adaptation.

6.1.5.1 Management of the risks of climate change – Disaster preparedness and disaster-risk management

As a signatory to the Sendai Framework for Disaster Risk Reduction, Germany, in the framework of its international cooperation, supports developing countries in their endeavours to analyse fundamental risk factors for their societies, with a view to reducing existing risks, preventing the emergence of new risks and managing residual risks. This includes precautions to protect critical infrastructure such as schools, hospitals and power stations. The BMZ's approach in this area is oriented to comprehensive risk management. It is a holistic approach that combines proven and innovative instruments from the areas of climate and disaster risk management, structure-building transitional assistance and social security. This approach addresses the full spectrum of disaster and climate risks in a systemic, cross-cutting manner, with a view to protecting successes achieved in development assistance. Germany's multilateral cooperation in disaster risk management includes, inter alia, its support for the United Nations Office for Disaster Risk Reduction (UNDRR), the World Bank's Global Facility for Disaster Reduction and Recovery (GFDRR) initiative and the International Federation of Red Cross and Red Crescent Societies (IFRC). The total support

provided by the BMZ in the area of disaster risk management amounted to 97 million EUR / 109 million USD in 2019 and 66.4 million EUR / 77.8 million USD in 2020.

6.1.5.2 InsuResilience Global Partnership – protecting vulnerable people against climate risks

The InsuResilience Global Partnership (IGP) is the central initiative for the expansion of financing and insurance solutions to guard against climate and disaster risks. Its focus is on countries and population groups that are especially poor and vulnerable. The Partnership now comprises more than 120 members. It operates 24 programmes, in a total of more than 100 countries. InsuResilience has the ambitious goal of providing financial protection against climate and disaster risk for 500 million people annually by 2025.

6.1.5.3 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. The majority (about 72 %) of NDCs – which are at the heart of the Paris Agreement and the achievement of its long-term goals – include goals relative to adaptation. Germany supports partner countries in designing their National Adaptation Plan (NAP) processes, which play a central role in achievement of adaptation goals. Pursuant to a revised, more-restrictive counting method, Germany is now supporting 54 partner countries in the planning and implementation of their NAP processes. It provides support both directly, as bilateral support, or indirectly, via international initiatives such as the NAP Global Network (NAP GN). The NAP GN is a global network for national adaptation planning. It was founded in 2014 by the BMZ, working in cooperation with a number of countries, for the purposes of supporting national and global coordination of donors in the area of climate change adaptation and of providing a forum for networking by experts and government representatives.

6.1.5.4 Agriculture

On the one hand, agriculture is affected particularly strongly by climate change. On the other, global food systems contribute significantly to GHG emissions. If the UN Sustainable Development Goals (SDGs) are to be achieved – especially SDG 2 (zero hunger), SDG 13 (climate action) and SDG 15 (life on land) – the agricultural sector will have to be transformed, in a manner leading to low-emissions, climate-resilient agricultural and food systems that are able to meet the food needs of a growing world population. For this reason, Germany is working with partner countries for such transformation – aimed at food security, rural development and agriculture.

In 2019, a total of about 1.8 billion EUR / 2.02 billion USD of the BMZ's funding for development cooperation went to the areas of food security, agricultural support and rural development. The BMZ's "One World, No Hunger" special initiative provided about 222 million EUR / 249 million USD in 2019, and over 293 million EUR / 334 million USD in 2020, for such efforts.

Between 2014 and 2021, a total of 295 projects for climate change adaptation and emissions reduction were carried out in the topic area "climate change and agriculture"[160]. In the

[160] The figures were obtained from analysis of the BMZ portfolio in the topic area "climate change and agriculture," for the period 2014 – 2021. The basis consists of technical-cooperation projects that were applied for by the BMZ between 1 Jan. 2014 and 31 Dec. 2021, and of financing contracts for research-cooperation projects that were concluded between 1 Jan. 2014 and 31 Dec. 2021, with an emphasis or partial emphasis on rural development (code LE 2 or LE 1).

process, 33.8 million EUR / 38.6 million USD (1.4 %) went to the One-World-No-Hunger (OWNH) action area “food security,” 405.3 million EUR / 462.7 million USD (16,7 %) went to the OWNH action area “rural development” and 1.61 billion EUR / 1.84 billion USD (66.7 %) went to the OWNH action area “agriculture.” A total of 2.42 billion EUR / 2.76 billion USD was spent, in the 295 projects, on promotion of climate change adaptation and/or emissions reduction in agriculture. For projects with a finance volume totalling 897.4 million EUR / 1.24 billion USD, climate change adaptation was pursued as a principal objective (Rio marker score for adaptation = 2). A total of 505.4 billion EUR / 576.9 billion USD was spent on simultaneous promotion of climate change adaptation and emissions reduction in agriculture. For projects with a finance volume totalling 61.2 million EUR / 69.9 million USD, emissions reduction in agriculture was pursued as a principal objective (Rio marker score for reduction = 2). An additional 931.5 million EUR / 1.63 billion USD were spent on projects partly aimed at climate change adaptation in agriculture (Rio marker score for adaptation = 1). For projects with a finance volume totalling 28.5 million EUR / 32.6 million USD, emissions reduction was pursued as a significant objective (Rio marker score for reduction = 1).

In the framework of its multilateral approaches, the BMZ has contributed over 30 million EUR / 34.3 million USD to the Adaptation for Smallholder Agriculture Programme (ASAP/ASAP+) being carried out by the International Fund for Agricultural Development (IFAD). The programme is designed to help small farmers in the Global South gain access to climate and environmental finance. The BMZ’s global project “Green Innovation Centres for the Agriculture and Food Sector” (“Grüne Innovationszentren in der Agrar- und Ernährungswirtschaft”) is also helping to create a better future for rural areas. In 2019 and 2020, the BMZ committed 63.75 million EUR / 75.42 million USD of climate-relevant financing to the project – and thereby promoted innovations that contribute to climate resilience and emissions reduction in the agriculture and food sector, with a view to increasing incomes of small farmers, boosting employment and bettering regional food supplies in selected rural regions of Africa and Southeast Asia. The project is cooperating with over 150 partner organisations from the civil society, associations, science, research and private enterprise sectors.

Numerous bilateral, regional and (other) global projects are also implementing measures in the areas of climate action, climate change adaptation and promotion of resilience. These include, for example, the global project “Soil Protection and Rehabilitation for Food Security” (“Bodenschutz und Bodenrehabilitierung für Ernährungssicherung”), which is aimed at restoring the fertility of damaged soils. Soil conservation, properly adapted crop rotations and careful water use lead to sustainable soil management, and enhance the resilience of local residents. The programme “Adaptation of Agricultural Value Chains to Climate Change” (“Anpassung landwirtschaftlicher Wertschöpfungsketten an den Klimawandel”) is supporting small farmers in Madagascar with suitably adapted weather information, insurance policies and structural-support measures such as education and cooperation.

In sub-Saharan Africa, livestock plays a vital economic role for more than 80 percent of households classified as impoverished. For this reason, the BMZ is operating its “Climate-Smart Livestock Systems” programme (“klimaintelligente Tierhaltungssysteme”), which promotes sustainable animal husbandry. In cooperation with local livestock owners, the International Livestock Research Institute (ILRI) and the World Bank, the programme is testing climate-resilient, low-emissions livestock-management strategies and establishing them on a broad basis via high-volume investment projects and digital applications. In the project

The portfolio analysis does not support any breakdown of the data by years. As a result, it is not possible to isolate the period 2019 – 2020 in this context.

“Promoting Rural Development in Uganda” (“Förderung der ländlichen Entwicklung in Uganda”), which is being co-financed by the EU, the BMZ is working to increase agricultural production and value creation in rural areas. The effort is focussed especially on supporting micro, small and medium sized enterprises (MSMEs), and small farmers, in founding start-ups, disseminating proven, climate-adapted cultivation methods and obtaining access to financial services. It is also especially emphasising efforts to improve the living standards of women and young people.

The BMZ has also been contributing to the financing of 17 international agricultural research centres (15 CGIAR centres, WorldVeg and icipe), via a budget item for funding of international agricultural research. Its support in this regard amounted to 20 million EUR / 22.4 million USD in 2019 and 35 million EUR / 40 million USD in 2020. The research centres develop and promulgate innovations that strengthen small farmers’ resilience against climate-change impacts and help make food systems more sustainable.

In addition, the federal government supports the United Nations Food and Agriculture Organization (FAO), in the framework of that organisation’s own food security programmes, to help farmers adapt to climate change and to reduce the agricultural sector’s contributions to climate change. In a participatory approach, researchers are working together with local partners to develop exemplary strategies and to implement them in regions of interest in Africa, Asia, Europe and South America.

Efforts to strengthen resilience against the impacts of climate change, for land users in Africa, are playing a special role in capacity-building. Land use is an especially important factor in Africa, since local ecosystem services there play an essential role in many livelihoods. For this reason, the question of what climate changes – with what consequences for land and water resources – African countries must expect is becoming more and more pressing. Together with partners from eleven 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 in West and Southern Africa – RSSCs), with a view to better equipping the countries in the region to make their own useful decisions with respect to issues such as land use and water supplies. Efforts to promote the education and development of young scientists, and the development of local research capacities in the region’s countries, are playing a central role in this connection. From 2010 to 2020, the BMBF has already invested more than 150 million euro in the establishment of the two science service centres.

6.1.5.5 Water

Water is the medium by which climate change most directly impacts people and ecosystems, and many economic sectors. Since the middle of the 20th century, anthropogenic climate change has brought about considerable changes in the global water cycle. This is having significant impacts on water resources, and on water supplies and sanitation, in the Global South and worldwide. In the 2019 – 2020 reporting period, therefore, about 430 million EUR / 486 million USD – or more than one out of every seven euros (14 %) – of Germany’s bilateral adaptation finance (budgetary resources, including grant-equivalents) went to the water resources sector.

A digital further-training system for the wastewater-management sector in Peru provides a concrete example of how the Federal Ministry for Economic Cooperation and Development (BMZ) is working to improve access to safe drinking water and sanitation, and is supporting local populations in climate change adaptation in the water sector. For local populations, such efforts are improving identification and reporting of climate hazards; improving

identification and implementation of adaptation measures; and improving the resilience, with respect to climatic fluctuations, of operational and financial decisions. In the provincial capital of Moquegua, the efforts have improved water-requirements management: water losses have been reduced from 46 % to 31 %, and per-capita water production has been decreased from 386 litres to 258 litres. As a result, resilience with respect to climate-change-caused water shortages has improved.

The BMZ's pertinent commitment cannot be quantified in the framework of the International Climate Initiative (IKI), since the thematic area "water" appears in a number of different IKI projects and funding areas:

In Grenada, for example, the IKI is co-financing two components of a Green Climate Fund (GCF) project that are aimed at developing the first climate-neutral water utility in the Caribbean region, in the form of a model that can be reproduced throughout the region. In addition to advising for the national water and wastewater management agency, regarding water and energy efficiency, the project is aimed at introducing renewable energies and supporting reductions of water losses.

In the Philippines, the IKI is supporting ecosystem-based adaptation measures in two river basin districts. The project is aimed at reducing the numbers of households at risk, and at improving water availability and water quality in selected water-catchment areas. In addition, the project is providing impetus for improvements of the water-governance system.

In the framework of the BMBF's "Global Resource Water" (GRoW) funding measure, research and development projects aimed at improving management, including forward-looking management, of water resources – and also in light of climate change – are being funded (inter alia, in Africa and South America) with funding totalling about 31.4 million EUR. As a result, since 2017 – and, with follow-on projects, since 2022 – an important contribution to implementation of the UN SDGs is being made in the water sector. In general, such efforts are focussed especially on promoting good governance in the water sector. This aspect includes providing stakeholder training that facilitates transfer of successful implementation and practices to other regions.

6.1.5.6 Ecosystem-based adaptation

Ecosystem-based adaptation (EbA) makes use of biological diversity, and of the services provided by natural systems, as part of a broad-based strategy for supporting local populations in adaptation to the negative impacts of climate change. EbA functions as a promising alternative, or complement, to traditional-style, technically oriented, "grey" measures. Its primary aims are to support protection, restoration and sustainable use of land and sea ecosystems, with a view to reinforcing societal and natural resilience and to mitigating the impacts of climate change. EbA measures are effective in many different ways. They are cost-effective, and provide many benefits, in addition to adaptation benefits pure and simple, for people affected by the impacts of climate change – including benefits in the areas of income, key services and needs, and well-being.

The political importance of EbA – also referred to as "nature-based climate adaptation solutions" – is growing. Pursuant to the IPCC[161], protection of biological diversity and ecosystems plays a decisive role in climate-resilient development in the face of climate hazards and their links to climate action and climate change adaptation. It is estimated that 30 – 50

[161] IPCC Climate Change 2022: Mitigation of Climate Change (ipcc.ch).

% of global ecosystems need to be protected – effectively and equitably – in this regard. More than 62 % of all NDCs include EbA as adaptation measures.

The projects being financed by Germany, for ecosystem-based adaptation, advise partner countries on ways of integrating and implementing the EbA approach within their planning processes. EbA measures are tested in model projects, and the results are processed and then disseminated. Ecosystem-based adaptation measures are used, for example, in the area of flood and coastal protection. Such protection can take the form of retention areas, or of protection and/or restoration of biologically diverse, resilient vegetation for water storage.

In the NDC Partnership, EbA approaches are funded at the request of partner countries, in the framework of their NDCs. In addition to contributing to the relevant bilateral and multilateral portfolios, the BMZ supports various initiatives that contain EbA approaches, such as the Legacy Landscapes Fund (amount committed in 2020: 82.5 million EUR / 94.2 million USD) and the Global Fund for Coral Reefs (amount committed in 2020: 3 million EUR / 3.4 million USD). Also, in 2019 and 2020, the BMZ committed 37 million EUR / 42 million USD) to the Blue Action Fund, for implementation of marine conservation projects in support of climate change adaptation in sea and coastal regions. Via the “MeerWissen” initiative, which is strengthening partnerships between marine research institutions in Africa and Germany, the BMZ is taking account of the interrelationships between the oceans and climate change.

Via the International Climate Initiative (IKI), the BMUV is advising partner countries on ways of integrating and implementing the EbA approach within their planning processes. In addition, it is supporting measures working to counter climate-related impacts such as erosion in coastal areas, water-catchment areas and mountain regions; droughts; and reduced soil fertility. The measures are also aimed at supporting adaptation in agriculture, animal husbandry, fisheries, aquaculture, water supplies, coastal protection and infrastructure. With this orientation, the EbA projects are helping to protect vital natural resources and provide “natural protection” against climate hazards.

In general, the projects’ focus has moved from pilot measures to mainstreaming and to broad-based upscaling of useful approaches. Integration of the private sector, and support for relevant political processes, also play an important role in ensuring that projects have lasting effects.

In 2019 and 2020, the International Climate Initiative has invested over 80 million EUR / 84 million USD in EbA. The Global EbA Fund (GEBAF), which was founded in December 2019, in cooperation with UNEP and IUCN, supports innovative approaches to ecosystem-based adaptation (EbA). It helps to improve understanding of EbA, planning and expansion of EbA processes, and access to funding for EbA measures. The GEBAF is creating incentives for new financing mechanisms and for investments on the part of the private sector. To increase its reach, many times over, the Fund makes use of established partnerships and networks.

6.1.6 Approaches for greenhouse-gas reduction

To reach the 1.5°C goal formulated by the Paris Agreement, we must reduce global GHG emissions by 43 %, with respect to 2019, and achieve greenhouse-gas neutrality by the middle of the century. That fact notwithstanding, after a brief decrease during the coronavirus pandemic, GHG emissions and the atmospheric CO_2 concentration again reached record levels. According to a report of the World Meteorological Organization, the global

surface temperature even climbed to 1.2°C of warming in 2020. The impacts of climate change manifest themselves first, and most strongly, in developing countries. And in those countries, the poorest people are the ones who suffer the most.

Consequently, the central goals of German development policy include contributing to global reduction of greenhouse gases. To achieve this goal, Germany is supporting partner countries in building low-emissions and climate-neutral economic and supply structures, and in carrying out socially equitable transformation. Such activities include expanding use of renewable energies; phasing out fossil fuels; reducing use of fluorinated greenhouse gases, which are extremely climate-harmful; and carrying out sustainable urban planning. Other measures areas include development of climate-conscious strategies for the mobility and waste management sectors, and the protection of natural carbon sinks.

The NAMA Facility was launched in 2012, as a multi-donor effort, at the initiative of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the British government. The NAMA Facility finances innovative, transformational Nationally Appropriate Mitigation Actions (NAMAs), and comparable national initiatives, that have strong national ownership and that contribute to low-carbon development. It works in developing and emerging countries worldwide. In the reporting period, two calls for projects were carried out. The annual call comprises 60 million euros from the BMUV and the UK, and it includes a special initiative. In spite of the postponement of COP26, and in spite of the global coronavirus pandemic, the year 2020 was a decisive year for international climate action. Via a special call for projects, the “Ambition Initiative – Supporting Ambitious NDCs for a Green Recovery” is supporting especially ambitious countries in implementing their NDCs and in linking them, immediately following the coronavirus pandemic, directly with a climate-friendly new economic start. For this call, and via the International Climate Initiative, Germany has paid 100 million euros into the NAMA Facility. Other donors have increased the amount to a total of 174 million euros. Thanks to its donors, the NAMA Facility was able to invest a total of more than 520 million euro in climate action projects by the end of 2020.

6.1.6.1 Energy

Cooperation in the area of energy is aimed at rapid transformation of the energy sectors of developing and emerging countries, leading to sustainable, needs-based and climate-friendly energy infrastructures, on all levels, that provide both energy security and climate protection.

In the process, the federal government is relying partly on experience gained with the Germany’s energy system transformation, and it is supporting both efforts to increase energy efficiency and efforts to expand use of renewable energies. Also, it is supporting needs-based solutions for use of renewable energy sources, in the interest of improving access to energy and reducing energy poverty in developing countries. The instruments for supporting the transformation of the energy sector include policy advising for our partner countries; building of institutional capacities and competencies; support for technology and know-how transfer; provision of innovative financing instruments; promotion of investment measures; and cooperation with regional and multilateral partners.

The energy sector accounts for one of the largest shares of bilateral climate finance. In 2020, commitments from budgetary resources, grant-equivalents and market funds, in the area of energy generation from renewable energies, amounted to a total of about 915 million EUR / 1.04 billion USD. In addition, about 1.33 billion EUR / 1.5 billion USD was

provided for energy distribution, demand-side efficiency measures, and research and further training in the energy sector.

The total volume of energy projects underway in 2020, in the framework of bilateral technical cooperation implemented by Gesellschaft für Internationale Zusammenarbeit (GIZ), on behalf of the German Government, amounted to about 1.02 billion EUR / 1.25 billion USD (including co-financing). The projects focus especially on political, structural and technical advising regarding favourable conditions for energy system transformations, and for local capacity-building. The BMZ-financed multi-donor platform of the "Global Energy Transformation Programme" ("Globale Energiewende") (GET.pro), for example, offers developing and emerging countries comprehensive advising services that support efforts to move energy system transformations forward. The programme also mobilises private investments in decentralised renewable energies, by building a pipeline of bankable investment projects and providing access to financing. Through the year 2020, a total of 53 decentralised renewable-energy projects were successfully connected with financial backers. The projects have mobilised an estimated 980 million EUR / 1.2 billion USD of investments; given over 11 million people access to sustainable energy; and saved 1 million tonnes of CO_2 per year.

The BMZ is supporting the Energising Development Partnership (EnDev) as the lead donor, and with the aim of eliminating global energy poverty. Since 2005, EnDev has helped 22.8 million people, 73,550 companies and 28,500 social institutions obtain sustainable access to electricity or modern cooking and heating technologies. In 2020, via EnDev, 0.9 million people, 1,100 social institutions and 19,680 SMEs obtained sustainable access to electricity or modern cooking energy. In 2020, the BMZ provided 10 million EUR / 11.12 million USD for EnDev.

The federal government has initiated the Africa Renewable Energy Initiative (AREI), aimed at expanding the use of renewable energies in Africa. At the Paris Climate Change Conference, the federal government committed itself to providing a total of 3 billion EUR in support of AREI by 2020. Validation of projects for 2019, representing funding of 318 million EUR / 356 million USD, remains to be carried out by AREI; validation is also pending for projects of the year 2020. With these projects, Germany probably met its commitment of 3 billion EUR / 3.43 billion USD by 2020.

Germany is making the case for a successive phase-out of fossil fuels by 2050 – and, in particularly for rapid termination of the expansion of utilisation of coal. In the interest of further reinforcing the transformational nature of energy projects in German development cooperation, the federal Government, acting on the basis of the "Report of the federal government on international coal financing, for the economic committee of the German Bundestag" ("Bericht der Bundesregierung zur internationalen Kohlefinanzierung für den Wirtschaftsausschuss des Deutschen Bundestages")[162] of January 2015, no longer supports new construction of coal-fired power plants, or the retrofitting of already decommissioned coal-fired power plants, in partner countries.

Via the International Climate Initiative, in partner countries the BMUV supports concrete, ambitious and lasting reform and transformation processes leading to low-carbon economic development. In this connection, it works to improve framework conditions on both the supply side and the demand side, with the aims of shortening the lead times for affordable low-

[162] Report of the German Government on International Coal Financing for the Economic Committee of the German Bundestag (Bericht der Bundesregierung zur internationalen Kohlefinanzierung für den Wirtschaftsausschuss des Deutschen Bundestages); online: https://www.bmwk.de/Redaktion/DE/Downloads/B/bericht-der-bundesregierung-zur-internationalen-kohlefinanzierung-fuer-den-wirtschaftsausschuss-des-deutschen-bundestages.pdf?__blob=publicationFile&v=5 .

carbon energy infrastructures and thereby reinforcing partner countries' climate-policy ambitions. Partner countries receive support oriented to their entire energy sectors, as well as support with regard to individual aspects, such as network integration of renewable energies, and energy-efficiency improvements in the buildings and industry sectors.

Since the inception of the International Climate Initiative (IKI), its thematic portfolio "Sustainable energy supply / Renewable energies / Energy efficiency" ("Nachhaltige Energieversorgung / Erneuerbare Energien / Energieeffizienz") has been a focus of funding oriented to emissions reduction. In the years 2019 and 2020, for example, the BMUV committed about 70 million EUR / 67 million USD of new funding for projects for promoting sustainable energy systems in partner countries.

In the framework of the project "Decarbonisation of the Chilean Energy sector" ("Dekarbonisierung des chilenischen Energiesektors"), the IKI is supporting the expansion of use of solar-energy and wind-power systems. Supplementally, it is supporting innovative technologies and approaches such as green hydrogen, integrated within renewable-energy systems, and sector coupling. To this end, the project identifies innovative projects and helps ready them for financing. The project "Clean, Affordable and Secure Energy for Southeast Asia" (CASE) is advancing the energy system transformation in the Southeast Asian region, with a focus on ambitious climate goals. In order to reorientate energy policies, CASE develops evidence-based solutions for central challenges such as the 70 % energy-demand increase that is forecast to occur by 2040. In such efforts, it cooperates extensively with relevant local stakeholders. CASE also supports coordination within Southeast Asia's energy sector, and it provides both technical and political assistance in this regard. The CASE project is currently building a knowledge platform and, as part of the Southeast Asia Energy Transition Partnership (ETP), also takes part in discussions of regional experts.

6.1.6.2 Transport

German development cooperation in this area is oriented to the aim of making climate-friendly, affordable mobility services available for growing urban populations worldwide. If global climate and development goals are to be achieved, and social and economic participation is to become a universal reality, the global transport sector will have to be transformed.

The federal government is actively supporting its partners in developing and emerging countries in connection with the establishment and expansion of sustainable public transport systems; the introduction of rules and measures for environmentally friendly goods and passenger transports; the revamping of vehicle fleets, in keeping with energy-efficiency and environmental criteria; and the improvement of urban traffic planning.

In 2016, and in the framework of the Habitat III Conference, the BMZ launched the "Transformative Urban Mobility Initiative" (TUMI), aimed at achieving sustainable urban mobility systems. In cooperation with eight international partner institutions (development banks, networks of cities, think tanks and NGOs), and with GIZ and KfW Development Bank, the initiative is supporting cities in developing and emerging countries in making their transport systems more sustainable.

From 2016 to 2020, the effort provided about 2 billion EUR / 2.28 billion USD worth of financing for sustainable mobility projects in the framework of Financial Cooperation (KfW Development Bank). It is estimated that more than 26.5 million people use the so-improved transport systems on a daily basis. As a result, about 1.5 million of tonnes of CO_2 emissions are being saved per year.

Along with a diverse range of projects for financial and technical cooperation, such as “Promotion of sustainable mobility, with renewable energies, in Morocco” (“Förderung nachhaltiger Mobilität mit erneuerbaren Energien in Marokko”) (6 million EUR / 6.8 million USD), or the support being provided for implementation of national climate protection goals in Mexico’s transport sector (4 million EUR / 4.6 million USD), the BMZ’s mobility portfolio also includes strategic bilateral partnerships. In Nov. 2019, for example, the federal government entered into a partnership with India oriented to green urban mobility, and provided 1 billion EUR / 1.14 billion USD for the effort. By 2022, over 7 million additional people will be using sustainable transportation on a daily basis as a result.

Via the International Climate Initiative (IKI), the BMUV supports the building of the structures needed for sustainable mobility. Its funding volume in this area amounted to a total of 55.08 million EUR / 62.7 million USD in the years 2019 and 2020. In countries in which motorisation is rapidly increasing, such as China, India and Vietnam, the International Climate Initiative’s “NDC Transport Initiative for Asia” project, for example, is promoting a comprehensive approach for decarbonisation of the transport sector. Also, it is supporting the project’s political partners in making their sectoral contributions to increases of Nationally Determined Contributions (NDCs), and in increasing their ambitions for relevant long-term strategies and the 2025 NDCs.

6.1.6.3 Forest policy

The German government’s international forest policy aims to halt deforestation and further forest degradation, and to preserve and restore forests as greenhouse gas sinks and treasure troves of biological diversity. In this connection, the federal government especially supports concepts oriented to forest conservation; development of forests’ carbon-storage potential; and sustainable land use without deforestation. Germany is one of the biggest donors worldwide in the area of international forest protection.

Via its GNU joint initiative with Norway and the United Kingdom, Germany is promoting integrated land-use programmes in the framework of the REDD+ approach, as well as private-sector investment in deforestation-free value chains. In the period 2015 – 2020, the three countries jointly provided 5.6 billion USD for forest conservation measures. The federal government's commitments in the years 2019 and 2020 amounted to about 980.6 million EUR / 1,115.6 million USD. The three countries have far exceeded the announcement they had made whereby they would provide at least 1 billion USD by 2020. Currently, funding is being concentrated on the protection and sustainable use of forests, in the interest of climate protection (REDD+) (for example, via good governance, participation of civil society and indigenous groups, monitoring of forest lands) and biodiversity protection. Funding of restoration of degraded forest landscapes, and promotion of deforestation-free supply chains, are also priorities of the federal government in international forest policy.

At the Paris Climate Change Conference in 2015, Germany, acting in cooperation with the New Partnership for Africas' Development (NEPAD; now, the African Union Development Agency (AUDA)) and the World Resources Institute (WRI), founded the African Forest Landscape Restoration Initiative (AFR100). This initiative is aimed at restoring about 100 million hectares of forest lands in Africa by 2030. With this aim, it is also supporting implementation of the “Bonn Challenge” at the regional level. In 2015, the Central African Forest Initiative (CAFI), aimed at supporting forest-protection and climate-protection policy in

the Congo Basin, was founded, with German participation.[163] CAFI is supporting numerous relevant measures, such as improved agricultural practices, agroforestry, participatory preparation of land-use plans, family planning and reforms for achieving good governance. In the context of CAFI, forest conservation primarily means poverty alleviation. To support CAFI, a trust fund (CAFI Fund) has been established. It is administered by the UN Multi-Partner Trust Fund office. Germany is the largest CAFI donor, after Norway.

In 2012, the BMZ established the REDD Early Movers (REM) programme, aimed at supporting REDD pioneers (also called Early Movers) who are already taking the initiative themselves in forest conservation for climate change mitigation, and at testing results-based REDD+ financing. To date, the BMZ has provided funding in the amount of 109.5 million EUR / 125 million USD for the programme. Norway and the UK are participating with about 68 million EUR / 77.6 million USD and 80 million EUR / 91.3 million USD, respectively (converted values). As of December 2020, the programme had already paid out about 190 million EUR / 217 million USD for about 45 million t CO_2 emissions reductions in Brazil, Columbia and Ecuador.

With regard to REDD+ and other implementation mechanisms for forest conservation (such as the Socio Bosque programme) Ecuador is a pioneer in Latin America. For some years now, the country's deforestation rate has remained constant, at a relatively low level. For the REDD Early Movers programme, BMZ funding in the amount of 11 million EUR / 12.6 million USD is available to Ecuador. Up to 70 % of the funding has been reinvested, in the framework of the "benefit-sharing" component, in local measures for forest conservation. Such measures include funding of forest conservation; financing of initiatives in indigenous and rural communities; activities for restoration of degraded forest lands; and funding and marketing of sustainable products from deforestation-free supply chains. The remaining 30 % of the funding goes toward strengthening structure-building measures in the area of the country's national forest and environmental policy.

In 2011, the BMUV, in cooperation with the IUCN, sent out invitations to a "Bonn Challenge" ministerial conference and initiated a Global Partnership on Forest Landscape Restoration (GPFLR), aimed at upscaling forest restoration techniques from the local-project level to large-area forest landscapes. The Bonn Challenge set itself the aim of beginning with the restoration of 150 million hectares of forests and forest landscapes by 2020. By 2020, a total of 61 countries, eight federal Länder and five organisations had made commitments adding up to an area of 210 million hectares. By 2020, the International Climate Initiative (ICI) provided more than 200 million euro for the restoration of forest landscapes. For five countries with long-standing commitments, the ICI-funded "Bonn Challenge Barometer" showed an implementation rate of 89 % of a total commitment of 30 million hectares of forest landscapes, with Pakistan and the U.S. exceeded their commitments.

Regional initiatives are important multipliers for the achievement of the 2030 goal for restoration of 350 million hectares of forests and forest landscapes. In 2019, European, Central Asian and Caucasus countries joined the Bonn Challenge's ECCA30 initiative and announced their intention, at the UN Climate Week, of restoring a total of 30 million hectares of forest landscapes by 2030. The World Resource Institute's Latin American initiative for restoration of 20 million hectares of forest landscapes by 2020 received 4.6 million EUR / 5.35 million USD of funding from the International Climate Initiative. By mobilising financing, the initiative was able to restore 8.2 million hectares of forest and protect 14.6 million

[163] The CAFI partner countries include: Cameroun, the Democratic Republic of the Congo, the Republic of Congo, the Central African Republic, Gabon and Equatorial Guinea.

hectares of forest. In 2020, 10 COMIFAC countries signed the Dakar Declaration on the Restoration of Forest Landscapes in West Africa.

Via the global “Deforestation-Free Supply Chains” project, the ICI is supporting cooperation with local stakeholders, governments and multilateral organisations, with the aim of developing and testing ways of achieving the following: How private-sector commitments to keep supply chains deforestation-free can more effectively be integrated within national policies and initiatives for combatting deforestation.

6.1.6.4 Waste management, and circular economies

In many developing and emerging countries, large fractions of organic waste, often in combination with poorly regulated waste management, produce significant GHG emissions. This issue especially involves methane emissions from landfills and waste heaps. Also, open waste incineration is widely practised in many countries around the world. According to recent findings, the soot such combustion emits is a significant factor in global warming. The federal government is placing high priority on establishing and expanding circular-economy systems around the world. According to the UN Environment Programme, a transition to circular economies, in combination with waste prevention and reuse of recycled materials, could cut global GHG emissions by 10 % to 20 %. Also, open waste incineration is widely practised in many countries around the world. According to recent findings, the soot such combustion emits is a significant factor in global warming. The federal government is placing high priority on establishing and expanding circular-economy systems around the world. According to the UN Environment Programme, a transition to circular economies, in combination with waste prevention and reuse of recycled materials, could cut global GHG emissions by 10 % to 20 %.

German development cooperation is funding the development of national waste management strategies and laws. It is supporting communities in planning and implementing concepts for avoidance, collection and recycling of waste, and it is funding infrastructure for climate-friendly waste treatment and recycling. The waste management techniques in focus in this effort include composting, mechanical-biological waste treatment, recycling and controlled energy recovery from waste (for example, utilisation of biogas and landfill gas). BMZ projects in this area – for example, in Serbia, Albania and Tunisia – are financed with funding from the German Climate Technology Initiative (DKTI) and the Initiative for Climate and Environmental Protection (IKU). Serbia, for example, is being supported in building capacities for recycling-oriented, integrated waste management system. In Indonesia, waste targets are being linked with climate targets. In preparation for measures for a climate-friendly waste management sector, capacities are being built – on both a nationwide and regional basis – in the areas of planning instruments, data management, know-how and financing models. At the same time, the project is creating positive synergies with an existing waste-infrastructure project of KfW Development Bank.

At the global level, the BMZ is working to advance cross-cutting knowledge exchanges and implementation of pilot projects, in PREVENT Waste Alliance[164] framework. This is occurring with respect to biowaste management in Ethiopia, for example. In general, German development cooperation emphasises funding of measures for waste prevention, which conserves resources and energy.

[164] https://prevent-waste.net/en/ "

From the perspective of the International Climate Initiative, Bhutan, Mongolia and Nepal all have great potential for reducing emissions of greenhouse gases and short-lived climate pollutants (SLCP) in their waste management sectors. For this reason, one International Climate Initiative project is aimed at capacity-building in these countries, on multiple levels, with focuses that include targeted improvements of the legal situation for NDCs and identification of suitable waste-treatment technologies. Since 2017, another ICI-funded project has been supporting Argentina, Indonesia and Mexico in developing measures and strategies for improving resource efficiency and climate change mitigation. For example, the effort developed a method for quantifying the potential that resource-efficiency measures have to reduce GHG emissions in value chains. In cooperation with the NAMA Facility, the BMUV is funding additional projects for reducing GHG emissions by improving waste management. This is occurring in India, for example.

6.1.6.4 Urban development

The German government views cities and towns as central players in endeavours to achieve the global sustainability agenda (Agenda 2030) and the global climate agenda (Paris Agreement). German development cooperation supports sustainable urban development in partner countries, as a field of action within the BMZ core area strategy “Responsibility for Our Planet – Climate and Energy.” Development and implementation of integrated urban development strategies reinforce climate change mitigation, and it strengthens resilience against the impacts of climate change. A special emphasis in this area is the building of infrastructure that both promotes low-carbon development and can withstand impacts of climate change. In 2019 and 2020, the BMZ, working via the KfW Development Bank, provided a total of 3.44 billion EUR / 3.93 billion USD for climate action in cities. In addition, in 2020 the BMZ invested an additional 795 million EUR / 908 million USD in technical cooperation projects for urban climate improvement and adaptation. Because cities often do not receive adequate financing for climate-friendly infrastructure projects, the BMZ supports them throughout the entire project-preparation cycle. For the early phase of project preparation, the ministry, in cooperation with the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), and the government of Luxembourg, created the “City Climate Finance Gap Fund.” Via a “one-stop-shop” approach, the Fund supports cities in developing and emerging countries in achieving their climate goals, by helping them translate low-carbon and climate-resilient approaches into strategies and financeable projects. The Gap Fund is implemented by the World Bank and the European Investment Bank (EIB), with financing of 20 million EUR / 22.8 million USD from the BMZ, and 25 million EUR / 28.5 million USD from the BMUV (since 2022 from the Federal Ministry for Economic Affairs and Climate Action (BMWK)). For the late phase of project preparation, the “C40 Cities Finance Facility” (CFF) supports cities in preparing their climate-friendly and resilient infrastructure projects to the point at which they are bankable, i.e., financeable. Since 2015, these efforts have facilitated investments in the amount of 569 million EUR / 650 million USD, for projects that will prevent 2.5 Mt CO2e of GHG emissions by 2050. Projects that are at an advanced stage are used as “lighthouse examples” from which as many other cities as possible can learn – and themselves become able to acquire adequate funding for climate-friendly infrastructure projects.

Since 2015, the thematic area “sustainable urban development” has been an overarching emphasis of the International Climate Initiative (ICI), which was established in 2008 by the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV). The funding volume for this area amounted to 15.5 million EUR / 17.7 million USD in 2020. The projects funded in this framework support partner countries in

developing strategies for addressing climate change in cities and in making their economic structures more sustainable and more climate-friendly. Also development of competencies and capacities at the national and municipal levels is accompanied by support in the areas of knowledge transfer, technology cooperation, policy advising and investments. The thematic emphases in this regard include digital transformation of cities / "smart city" approaches, and climate-resilient urban development.

In the BMBF's international funding measure "Sustainable Development of Urban Regions" (SURE), a total of eleven collaborative research projects, working in cooperation with partner regions in China and Southeast Asia, are developing strategies, for rapidly growing cities and urban regions, relative to sustainable urban development and to resilience improvement. From 2019 through 2027, the BMBF is providing nearly 40 million EUR for this purpose.

In the BMBF's CLIENT II funding priority, and via demand-oriented projects, international research cooperation with selected developing and emerging countries is being established, aimed at joint development of strategies for the areas of climate, the environment, resources and energy, and able to help address concrete challenges in the partner countries. In this area, bilateral collaborative network projects are being funded in over 30 countries (about 145 million EUR, 2017-2025).

6.1.7 Mobilisation of private investments in climate change mitigation, and adaptation measures, in developing and emerging 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. Consequently, Germany uses financial cooperation instruments to mobilise private funding for climate-relevant activities in developing countries.

To direct financial flows in keeping with the spirit of Article 2.1c of the Paris Agreement, one must apply a holistic approach that can both mobilise significant funding for climate transformation and help bring about lasting, systemic change in financial markets. In this regard, both the public sector and the real economy have important roles to play. The state establishes the framework conditions for climate-friendly and climate-resilient investments, and it can create incentives for climate-relevant investments via climate-aware fiscal policies. The state also has a regulatory role to play with regard to sustainable structuring of the finance sector *(sustainable finance*). For its part, the private sector is called on to finance the transformation, and to bring climate awareness to its activities. Relevant measures are being carried out in the following areas:

6.1.7.1 Capacity building for implementation of Art. 2.1c

The federal government supports advising of policymakers in implementation of reform processes within the meaning of sustainable finance, and in creation of political and regulatory frameworks that promote private climate-relevant investments. In connection with efforts aimed at sustainable finance, Germany supports the rigorous application of ambitious environmental, social and governance criteria (ESG) to investment decisions and to the risk management of local financial-market players. Also, Germany promotes beneficial financial frameworks and standards in partner countries, in the interest of long-term mobilisation of capital for social and ecological transformation.

Since 2018, in the framework of the project “Green Finance Market Regulation and Green Bonds” (“Grüne Finanzmarktregulierung und grüne Anleihen”), the BMZ, working via the GIZ, has supported the Brazilian ministry of economics in making the Brazilian finance sector more sustainably oriented. The project is also cooperating closely with the Brazilian central bank, with a view to strengthening sustainability-oriented regulation and supervision of the finance sector. By July 2020, thanks in part to the project’s efforts, the volume of loans from private financing institutions, for green investments, had grown by 75 % over the previous year’s level.

In Vietnam, the BMZ, working via the GIZ project “Macroeconomic Reforms / Ecological Growth” (“Makroökonomische Reformen/Ökologisches Wachstum”), is supporting development of coherent national economic, financial and fiscal policies – especially with regard to their green components. Inter alia, the green banking system is being strengthened, and the green capital market is being developed. In particular, the project is promoting local capacity building, and it is supporting development of regulatory and funding policies oriented to green bonds and green loans. Also, the project is supporting the development of a green taxonomy, climate-oriented risk management and transparent financial reporting.

In 2019 and 2020, the BMZ provided about 1.5 million EUR / 1.67 million USD for activities of the International Monetary Fund’s (IMF’s) Climate Change Capacity Development programme. The programme focuses on capacity-building in finance ministries and central banks in partner countries, and it supports the Coalition of Finance Ministers for Climate Action (CFMCA) in implementation of relevant fiscal-policy measures such as a CO_2-pricing system.

The International Climate Initiative (ICI) of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) also is intensively involved in efforts pertaining to financial markets. With a view to increasing climate-oriented funding, the International Finance Cooperation’s (IFC’s) project “Scaling up Climate Finance through the Finance Sector – 30 by 30 Zero” supports creation of domestic markets, in partner countries, for financing of climate projects. To this end, the IFC implements measures at the policy, market and financial-market levels. In addition to capacity-building in relevant financial institutions, this entails adaptation of finance-sector strategies in keeping with the pertinent NDCs. Also, the share of climate-oriented loans, with regard to the participating banks’ overall loan portfolios, is to be considerably increased by 2030, and climate-related and coal-related risks are to be reduced. As a complementary measure, climate-oriented investments are to be promoted via the development of green bonds. The Latin American Climate Asset Disclosure Initiative, an ICI project of the Federal Ministry for Economic Affairs and Climate Action (BMWK), is supporting institutional investors in Peru and Mexico by providing training in the area of reporting.

With other ICI projects, the BMWK is helping to finance NDCs in partner countries. In Ethiopia and South Africa, the ICI project “Aligning Financial Flows” is identifying evidence-based options with a view to harmonising financial flows with the Paris Agreement – and to highlighting the kinds of ambitious mitigation and adaptation measures that could appear in future NDCs and long-term strategies of African countries. The project’s important components also include knowledge transfer – promoting sharing of findings from target countries with a wide group of African countries that are taking similar approaches.

6.1.7.2 Private-sector mobilisation and innovative financing instruments

KfW Development Bank and its subsidiary DEG leverage private funding in connection with their climate-relevant activities in developing and emerging countries. In 2019, KfW

Development Bank mobilised private climate funding of 531.4 million EUR / 595 million USD, as calculated with the OECD method.[165] In 2020, the amount decreased to 64.3 million EUR / 73.4 million USD. In keeping with its mandate, the DEG works exclusively with the private sector. In the process, it accepts risks that commercial banks and investors either will not / cannot accept or will accept only in part. The DEG provides tailored financing packages in which private investors and commercial banks take stakes. The private climate funding mobilised by DEG loans or stakes is also calculated with the OECD method. As calculated with this method, the DEG mobilised private funding in the amount of about 238.5 million EUR / 267 million USD in 2019 and about 128 million EUR / 146 million USD in 2020.

Via financial cooperation, Germany participates in numerous green, innovative financing instruments. For example, since 2020 the federal government, working via KfW Development Bank, has participated in the capital for the “Facility for Energy Inclusion – OnGrid (FEI-OnG)” (in cooperation with the African Development Bank, the EU and Norfund), and thereby contributed to the BMZ initiative “Green People’s Energy for Africa” (“Grüne Bürgerenergie für Afrika”) and to mobilisation of institutional investors for that funding purpose.

Since early 2020, KfW Development Bank, working on behalf of the BMZ, and in cooperation with EIB, EU Munich RE and the African Trade Insurance Agency, has participated in the “African Energy Guarantee Facility,” which provides guarantees for sustainable energy investments, and thereby reduces the investment risks for private investors. It is expected that the Facility will mobilise some 1.4 billion USD worth of private investments in energy projects in Sub-Saharan Africa.

Private funding for climate action and adaptation, via knowledge generation and capacity building, is also mobilised via technical cooperation.[166] From 2016 to 2019, and in the framework of a public-private partnership, the development of green bond markets in G20 emerging countries was supported. The results of the relevant cooperation with Skandinaviska Enskilda Banken (SEB), which is considered to be a pioneer in the area of green bonds, included numerous technical training courses for capital market participants, the first available online training course on sustainable finance and a series of online events on green bonds.

Via the International Climate Initiative, the BMWK also funds various “blended finance” vehicles, as well as other fund structures that help leverage private-sector financing and minimise the risks for it. For example, the federal government is an anchor investor for the “Emerging Market Climate Action Fund,” a fund of funds that is managed by Allianz Global Investors and advised by EIB. It has an investment goal of 500 million EUR. The fund’s resources are used to support infrastructure and climate funds that finance environmental projects, and new projects for adaptation to climate change and for climate change mitigation, in developing countries.

Also via the International Climate Initiative, and with funding of 30 million USD, the BMWK is supporting the Climate Finance Partnership (CFP), a structured equity fund that is being managed by Blackrock. The public-sector financiers finance the riskiest tranche of the fund (blended finance structure), in order to mobilise private investors. This risk cover reduces

[165] The OECD is working to develop an international standard for measuring mobilised private funding. For a number of financing instruments, methods have already been developed that are now in use. In the interest of obtaining a realistic picture, effort is made to apply a conservative definition of causal mobilisation, and to allocate mobilisation success fairly.

[166] Due to the lack of an official method, it has not yet been possible to quantify the mobilisation effects of technical cooperation.

the investment barriers for private financial actors in connection with renewable energies in developing and emerging countries. To date, the Fund has mobilised a total of 670 million USD (status as of Nov 2021), from countries, philanthropists and private investors, and it has an above-average mobilisation factor: 1:4.

In cooperation with the EU, Sweden, the Netherlands and Austria, Germany is funding the "GET.Invest" programme, which is aimed at mobilising private investments for decentralised renewable energy projects. In the programme, market analyses are being carried out, matchmaking events are being organised and preparation of projects is being supported. Between 2016 and 2020, over 270 projects were supported, and 86 projects were successfully connected with a financier.

6.2 Technology development and transfer

6.2.1 General information

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.

In the area of climate technology, the thematic areas / technology fields Low Carbon Energy, Climate Smart Cities and Resilient Rural Development are of particular importance for German development cooperation.

In the area of technology cooperation, Germany closely supports the technology mechanism under the UN Framework Convention on Climate Change and its organisations: Technology Executive Committee (TEC) and Climate Technology Centre and Network (CTCN). Since 2013, Germany has voluntarily supported the TEC with contributions totalling 650,000 EUR / 767,142 USD and CTCN with funding totalling 1.05 million EUR / 1.24 million USD.

Via the German Climate Technology Initiative (DKTI), the BMZ finances modern, climate-friendly and climate-adapted measures in developing and emerging countries. The measures, which often involve infrastructure, promote reductions of GHG emissions and adaptation to climate change. In 2019 and 2020 a total of about 3.86 billion EUR / 4.37 billion USD in project funding was committed from this facility.

Via the BMBF's CLIENT funding priority (International Partnerships for Sustainable Innovations), international partnerships in research, development and implementation of environmental and climate protection technologies have been built since 2010, via model projects. The funded cooperative efforts have included cooperations with Brazil, Russia, India, China, South Africa, Vietnam and Chile (about 60 million EUR / about 67 million USD; 2010–2017).

With CLIENT II, an updated follow-on measure, international partnerships in the areas of climate, the environment and energy are being funded. The collaborative research projects being funded in this effort are designed to help achieve the following: reduce environmental pollution in the partner countries; utilise natural resources smartly and efficiently; assure a reliable, clean and affordable energy supply for all segments of the population; and contribute to global action and adaptation to climate change and natural risks. The regional

emphases for the cooperation lie in China, Vietnam, Central Asia, South America, part of Africa and Iran. In the period 2016–2023, a total of about 100 million EUR / 118 million USD of BMBF funding has been earmarked for implementation of CLIENT II.

6.2.2 Energy sector

GET.pro is a multi-donor project (EU, DE, NL, SE, AT) with the aim of improving, via a coordinated European approach, the bases for investments in a global energy transformation, in order to contribute to equitable, climate-friendly development around the world. It focuses on mobilising investments in decentralised renewable energies and in advising for transformation. In cooperation with French and Spanish development agencies (AFD, Expertise France, AECID), the project is also implementing the third phase of the Covenant of Mayors in Sub-Saharan Africa (CoM SSA III), with the aim of promoting sustainable, climate-resilient urban development in Africa. The project is also providing the secretariat for the Africa-EU Energy Partnership (AEEP), and thereby promoting strategic political dialogue, on an equal footing, between the two continents. Via the GET.invest instrument, the project supports project developers and companies in developing bankable projects, thereby helping to close the gap between the available climate funding and the many project approaches, not all of which are of convincing quality. GET.transform supports partner countries and regions in shaping their energy system transformations. It does this via structured advising on creation of the necessary political and regulatory framework conditions. By providing basic financing totalling 12.6 million EUR / 15.02 million USD, the BMZ has facilitated the mobilisation of significant co-financing (April 2018 through December 2020: about 44 million EUR / 52.41 million USD). Through the year 2020, a total of 53 decentralised renewable-energy projects were successfully connected with financial backers. The projects have mobilised an estimated 980 million EUR / 1.2 billion USD of investments; given over 11 million people access to sustainable energy; and saved 1 million tonnes of CO_2 per year.

6.2.3 Transport sector

Germany is known for sustainable solutions and innovative concepts along the entire mobility and logistics chain. The German Partnership for Sustainable Mobility (GPSM) is the key contact partner for sustainable mobility and logistics solutions from Germany. The GPSM, a professional network involving industry, science 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, and increase the ability of subnational actors to plan and introduce climate-friendly technologies in the transport sector.

6.2.4 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. 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.

Through its develoPPP.de programme, the 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, and wish to expand their local operations in the areas where they are investing, can receive financial and technical support in the programme. Nearly 2,700 development partnerships have been initiated since the start of the programme in 1999. In 2019 and 2020, a total of 683 developmentally active projects were supported, with a total of 624 million EUR / 712 million USD, of which the privately leveraged share was 56% (about 350 million EUR / 400 million USD). Some of these were considered climate-related because they involved investment in renewable energy, energy efficiency, water treatment, recycling / circular economy, biodiversity or forestry.

With the Project development programme for developing and emerging countries (PEP), one of the important pillars of the German Energy Solutions Initiative (Exportinitiative Energie), the BMWK supports small and medium-sized enterprises (SMEs) that offer climate-friendly energy technologies in gaining entry into especially difficult markets that often are just beginning to develop. Like the German Energy Solutions Initiative itself, PEP resulted after the German Bundestag asked the BMWK to dovetail its foreign trade promotion with its development cooperation (BT-Drs. 15/4868 and 16/4962).

Currently, PEP is being carried out in ten African countries, three countries in South and Southeast Asia and in three Middle Eastern countries.[167] The programme could be expanded to other countries in those regions if promising opportunities for such expansion arise. Also, PEP could be expanded to Central and South America.

To obtain the best-possible links with development cooperation, the BMWK has commissioned the GIZ to carry out the measures that are primarily oriented to market preparation. The country selection is based on the areas in which the GIZ already – normally, as a result of contracts with the BMZ – has established structures and networks and has gained experience (especially in the energy sector) that PEP can build on. Business partnerships in which both sides are on an equal footing are being sought.

In countries/areas in which PEP is not being carried out, because the countries have reached a higher level of development (North Africa, South Africa and Namibia), the measures of the German Energy Solutions Initiative apply.

6.3 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, science 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

[167] Senegal, Mali, Ghana, Côte d'Ivoire, Nigeria, Kenya, Zambia, Botswana, Madagascar, Mauritius, Ruanda, Uganda, Vietnam, Cambodia, Bangladesh, Pakistan, Lebanon (x) and Jordan (x).

the Biennial Report in the Annex and CTF Table 9). In keeping with national priorities, the support measures for capacity building are designed to be context-specific and results-oriented. In this work, the German Government uses its range of international cooperation instruments and institutions to build capacities, at the individual, institutional and systemic levels, in the area of climate and development. Sample descriptions of capacity-relevant measures and initiatives in the areas of emissions reduction and climate adaptation, and at the sector level, are provided in the relevant chapters, 6.1.4, 6.1.5, and 6.2, and in CTF Table 9 in the Biennial Report.

7 Vulnerability, climate impacts and adaptation measures

7.1 Adaptation policy in Germany

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 German strategy for adaptation to climate change (DAS)

The long-term aims of the DAS are to reduce the vulnerability of natural, social and economic systems to climate change impacts, to increase the ability of such systems to adapt and to increase exploitation of possible opportunities in this connection. 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 the cross-cutting areas of a) civil protection and disaster management and b) spatial, regional and physical development planning.

In order to flesh out the DAS, the federal cabinet approved an initial Adaptation Action Plan (APA I) in 2011[168]. APA I underpins the DAS with specific federal government activities and identifies links with other national strategy processes. The first DAS progress report[169] and an Action Plan II were adopted by the German government in December 2015. In October 2020, the Action Plan for Adaptation III (APA III) was adopted, along with the second DAS progress report.

[168] German Federal Government (Bundesregierung 2011).
[169] German Federal Government (Bundesregierung 2015).

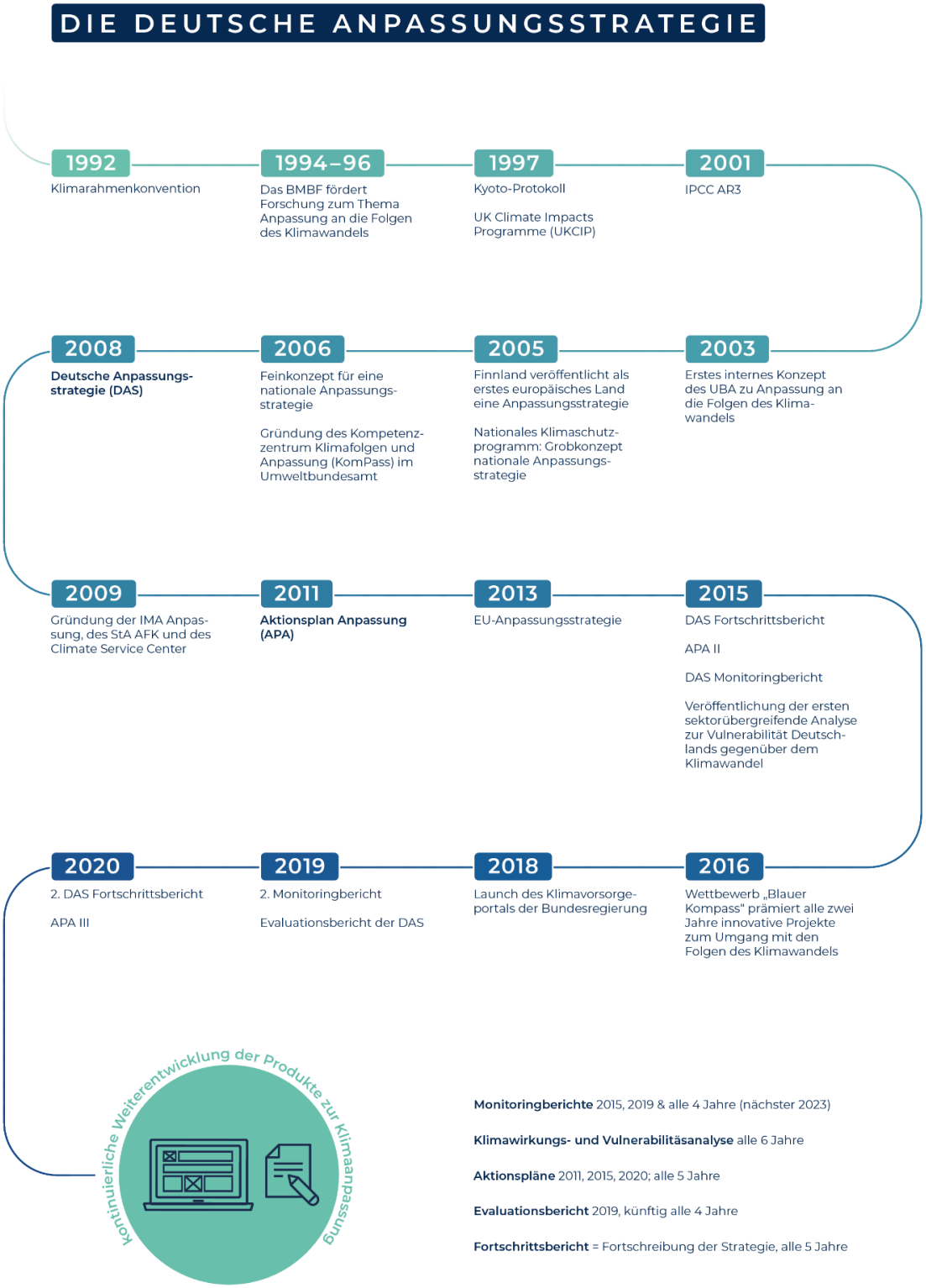


Figure 33: Chronology, DAS, APA and progress report (Source: German Environment Agency (UBA), own draft)

At the end of 2015, the federal government began to establish a comprehensive portfolio of climate services and climate change adaptation services, to support the implementation of DAS; their main task is to deliver the required climate services reliably over the long term.

7.1.2 Coordination of work for DAS

Within the federal government, the work is supported and coordinated under the leadership of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), via the Interministerial Working Group on Adaptation to Climate Change (IMAA). Within the IMAA, and under the chairmanship of the BMUV, all federal ministries work together, coordinate their activities with each other and continually set new goals, with the purpose of providing the necessary basis for climate change adaptation in Germany. The cooperation structures in place have proven to be successful. 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 and Sustainability (BLAG KliNa). This committee supports cooperation with the Länder. Via the StA AFK[170], the specific strategies and measures of the state (Land) administrations are taken into account in the work for DAS.

Key DAS products and updates are adopted through federal cabinet decisions.

In 2006, to support the design and further development of a national strategy for adaptation to climate changes, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) established a Competence Centre on Climate Impacts and Adaptation (KomPass), within the German Environment Agency. 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.

On the basis of the methods agreed on by the IMAA, a reporting system for the planning process for climate change adaptation in Germany was established. The process can be divided into four phases that are oriented to the policy cycle[171] for adaptation.

[170] For additional information about the precise composition of the IMAA and StA AFK, cf. Bundesregierung (2015).
[171] For further information about the policy-cycle model for adaptation, cf.: Vetter A., Chrischilles E., Eisenack K., Kind C., Mahrenholz P., Pechan A. (2017): Anpassung an den Klimawandel als neues Politikfeld. In: Brasseur G., Jacob D., Schuck-Zöller S. (eds) Klimawandel in Deutschland. Springer Spektrum, Berlin, Heidelberg

Figure 34: Reporting system for DAS (Source: German Environment Agency (UBA), own draft)[172]

7.1.3 Activities of the German Länder

Since the first progress report on DAS 2015, the Länder have become increasingly focussed on the thematic area of climate change adaptation. In Oct. 2020, the federal Cabinet adopted the second DAS progress report, which outlined future emphases for climate change adaptation in Germany. In addition, the federal government presented the third Action Plan for Adaptation, with over 180 specific climate action measures, including measures relative to all federal ministries. In connection with the adoption of the 2020 DAS progress report, several Länder have expanded and fleshed out the legal framework for climate change adaptation, either by adopting relevant laws (or, in some case, by including climate change adaptation as an element of climate protection acts) or by adding climate-change-adaptation sections to sectoral laws. In nearly all Länder, adaptation strategies and/or measures plans were adopted or updated. Also, interdepartmental and/or inter-agency bodies for administrative cooperation were established. And more and more

[172] translation: Fortschrittsberichte der DAS = DAS Progress Reports; Berichtswesen der DAS = The DAS reporting system; Monitoring - Klimawandel; Folgen des Klimawandels; Fortschritt beim Anpassungsprozess; Monitoring - Climate change; climate change impacts; progress on adaptation; Klimawirkungs- und Vulnerabilitätsanalyse - Anfälligkeit gegenüber den Folgen des Klimawandels = Climate impact and vulnerability analysis - Vulnerability to climate change impacts; Aktionspläne - Vereinbarung und Priorisierung geeigneter Massnahmen und Instrumente = Action Plans - Agreeing and prioritising appropriate measures and mechanisms; Umsetzung von Anpassungsmassnahmen = Implementing adaptation measures; Evaluierung - Prozess und Umsetzung (Output) = Evaluation - Process and implementation (output)

network structures outside of administrations – for example, structures including companies or representatives of civil society – are being established, in addition to the structures of this type that were already in place.

Some Länder are making use of the funding options offered by the federal government (such as its urban development promotion programme, which is redesigned as of 2020; and the BMUV funding programmes “Measures for climate change adaptation” and “Climate change adaptation in social institutions”) and the EU (such as the European Social Fund). To some extent, the Länder have funding programmes of their own in place that complement such federal and European programmes. The challenges presented by climate change have increased the need for funding adaptation measures at the regional level. In the interest of providing better support to regions and municipalities in this regard, the funding options at the EU, federal and Länder levels need to be coordinated more effectively.

Nearly all German Länder either have an indicator-based system in place for monitoring climate changes, climate impacts and adaptation measures or are in the process of establishing such a system. Many Länder design their systems in keeping with the federal government's monitoring reports, and simply add regionally specific indicators. While most such indicator systems focus on climate impacts – “impact indicators” – some Länder are also developing “response indicators” focussing on adaptation measures.

Here as well, as in connection with monitoring, the Länder make use of existing federal methods wherever possible, such as the guide to climate-impacts and vulnerability analyses (which was prepared with the help of the Länder) (Buth et al. 2017)[173]. The purpose of the guide, with its methodological recommendations for execution of climate-impacts and vulnerability analyses, is to facilitate intercomparison of sectoral and cross-sectoral studies at the federal and Länder levels. Overall, this can enhance federal-Länder consistency in results and assessments. The Länder define their own priorities for analyses and research projects, in keeping with their own regional needs.

The Länder also make use of the federal government's methods in developing their own methods for evaluating adaptation strategies. The methods, which were developed for the first DAS evaluation (such evaluations are to be carried out regularly in future), have been published as a guide.[174] As a result, the Länder are in a position to profit from evaluations carried out at the federal level.[175]

The federal government and the Länder also cooperate effectively via the German Climate Preparedness Portal (KLiVO[176]). The federal government's web portal provides a wealth of data and information about climate change and climate change adaptation. The Länder have helped design the portal, but they also offer their own climate preparedness services, and they also participate in the KlimAdapt[177] network. Plans call for this cooperation to be

[173] The guidelines on vulnerability were published in 2017, as recommendations of the Interministerial Working Group, and they are regularly revised.
[174] Kind, C., Kaiser, T., Gaus, H. (2019) https://www.umweltbundesamt.de/publikationen/methodik-fuer-die-evaluation-der-deutschen
[175] Due to the differences in structure between the adaptation processes at the federal level and those at the Länder level, and between the processes of the various Länder themselves, the methods developed for evaluation of the DAS cannot be unconditionally transferred to other levels. For this reason, the guide contains general information on strategy evaluation. On that basis, it also provides an overview of aspects that should be taken into account in carrying out evaluations. Finally, it covers central components of evaluations.
[176] www.klivoportal.de
[177] The KLiVO Portal, which was approved in connection with the first DAS progress report (2015), currently comprises: Deutscher Klimadienst (DKD) and an array of services related to climate change adaptation (KlimAdapt). The DKD office is sited at Deutscher Wetterdienst (DWD), and the BMDV serves as the lead institution for it. The KlimAdapt office is sited at the German Environment Agency (UBA), within the Competence Centre for Climate

continued and expanded, in order to better enable adaptation stakeholders at the regional level to address climate change adaptation.

Strategic cooperation between the federal government and the Länder has also been intensified in recent years. It ranges from work initiated by the Permanent Committee on Adaptation to the Consequences of Climate Change (StA AFK) to tasks that are usually handled by other federal-Länder bodies, with the involvement of the StA AFK. For example, in spring 2017, the federal-Länder ad-hoc working group “Health-related climate change adaptation” (“Gesundheitliche Anpassung an die Folgen des Klimawandels”), which was led by the BMUV and the Federal Ministry of Health, published “Recommendations for Preparation of Heat-Wave Action Plans for Protection of Human Health” (“Handlungsempfehlungen zur Erstellung von Hitzeaktionsplänen zum Schutz der menschlichen Gesundheit”), which had been prepared under commission to the StA AFK (BMUB 2017). The recommendations were prepared for municipal authorities, to assist them in developing regionally adapted action plans for heat waves. The purpose of such plans is to prevent heat-related and UV-related illness and death. The ad-hoc working group has become a permanent group, as part of the “Health in Climate Change” (“Gesundheit im Klimawandel”) Authorities’ Dialogue (Behördendialog) format.

Another example of the intensified cooperation between the federal government and the Länder is the agreement that has been reached on procedures for addressing challenges of future climate hazards such as accelerating sea-level rises. The increasing use of vertical (federal government – Länder – municipalities) and horizontal (cross-sectoral) policy integration is of great importance. For example, the bodies responsible for climate change adaptation, within federal-Länder ministerial conferences, are being more systematically involved in the work of the StA AFK. Increasing consultations on strategic goals, between the federal government and the Länder, could intensify climate change adaptation in Germany.

A permanent focus on the topic of climate adaptation, in the bodies of the conferences of specialised ministers of the Länder, could be another way to improve the cooperation between the federal government and the Länder. For example, a resolution of the Conference of Environment Ministers at the 90th Conference of Environment Ministers established a standing committee on “Climate Change” within the Federal/Länder Working Group on Water Issues (LAWA-AK). The committee focuses on the impacts of climate change on the water-resources sector, and it derives and prioritises required actions. Such work includes reviewing climate-change-related conflicts of objectives between the water-resources sector and the agriculture/forestry sector, with the aim of developing options for resolving them. The work of the LAWA-AK is expected to complement that of BLAG-KLiNa’s (see above) AFK standing committee, which is responsible for climate change adaptation, and complement the further development of the DAS.

Currently, LAWA AK’s small group on climate indicators is preparing a concept for climate-impacts monitoring in the water-resources sector; the effort is being coordinated with relevant work at the federal level. In the medium term, this work is expected to develop a consistent climate-impacts monitoring system, approved by both the federal government and the Länder, for the water-resources sector.

In April 2019, the conference of ministers of agriculture approved an agenda for adaptation of the agriculture and forestry sectors, and the fisheries and aquaculture sectors, to climate

Impacts and Adaptation (KomPass), and the BMUV serves as the lead institution for it. All of the services available from DKD and KlimAdapt are presented on the German Climate Preparedness Portal (KLiVO Portal).

change.[178] The agenda outlines the areas that are particularly affected by climate change and for which concrete measures need to be developed. The measures programme is currently being prepared under commission to the conference of ministers of agriculture.

7.1.4 Second progress report on DAS (2020); EU and international context

To be effective, climate change adaptation in Germany has to be carried out jointly by the federal Government, the Länder, the municipalities and other societal stakeholders. This is clear in light of current findings and results on climate impacts and adaptation measures (see the second progress report on DAS, 2020). In light of the conclusions the IMAA has derived from that report, it is clear that, in the coming reporting period, three thematic areas in particular will need to be emphasised in strategic further development of the DAS:

- Development of a vision for a climate-resilient Germany in 2060, and of pertinent goals that are specific, logical and consistent and verifiable. The IMAA plans to develop this vision in cooperation with the Länder, and with a time horizon at the year 2100. In the process, any key points of the EU adaptation strategy will be taken into account. For the goals developed in connection with the vision, in the various individual areas of action / clusters, the IMAA will describe the conditions under which they can be attained.
- Improved effectiveness assessment in connection with development of measures for the Action Plan for Adaptation. The measures proposed by the government network on climate change and adaptation (Behördennetzwerk Klimawandel und Anpassung) provide an important basis for discussion, and they are in future – to the extent possible – to be assessed regarding their effectiveness. The network's proposals have been made on the basis of a) the most-prominent climate impacts, and needs for action, that result from the climate-impacts and vulnerability analysis, and b) criteria-based individual assessment.
- An inventory of the federal government's expenditures for climate change adaptation, including the expected benefits in the various relevant areas, and a survey of the potential damage and economic effects resulting from climate change and adaptation measures in Germany. The German Environment Agency (UBA), with the help of the government network (Behördennetzwerk), supports the IMAA in the development of a method for such an inventory.

The format for the interministerial working group that controls the climate change adaptation process at the federal level has proven to be a success. This also applies to the federal/Länder body under the BLAG KliNa "Permanent Committee on Adaptation to the Consequences of Climate Change" (StA AFK) – and to supporting organisational formats such as the federal/Länder experts' discussions on "climate impacts" and "Interpretation of regional climate-model data."

The policy process for climate adaptation in Germany is being carried out in the context of European and international strategy processes for climate adaptation. Germany contributes actively to the work at the international and European levels, and it is represented in various bodies (including: Implementation of the European Adaptation Strategy).

[178] The agenda has been published on the website of the Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft 2019): https://www.bmel.de/SharedDocs/Downloads/DE/_Landwirtschaft/AMK-12-04-19-Agenda-Anpassung-Klimawandel.html

Das EU Climate Law addresses both the topic of climate change mitigation and the topic of climate change adaptation. It calls for the relevant EU institutions and the Member States to make continual progress in improving their adaptability, strengthening their resilience and reducing their vulnerability to climate change. To this end, the Member States are called on to develop and implement national adaptation strategies and plans. Reports on the progress made by the EU as a whole, and on the national progress made by the Member States, are to be regularly submitted to and evaluated by the European Commission.

In February 2020, COM presented a revised draft of an “Implementing Act – Reporting on national adaptation action,” and it opened the relevant public consultation process. The draft legislation fulfils the provisions on reporting in the Governance Regulation (Annex VIII Part 1 p. 69) and the UNFCC. According to these provisions, the key topics covered by such reports include: the main purposes and goals, and the institutional framework, for adaptation measures; projections relative to climate change, adaptation capacities, adaptation plans and strategies; the monitoring and assessment framework; and progress made in implementation.

In the Paris Agreement, climate change adaptation and climate change mitigation are treated as equally important pillars of international climate policy. Via its global adaptation goal, the Paris Agreement is aimed at advancing improvements in adaptation capacities; improvements in resilience; and reductions in vulnerability to climate changes. The second DAS progress report discusses Germany's international responsibility in the framework of international climate policy.

At the same time, additional multilateral framework agreements of the United Nations are of relevance to the issue of adaptation to climate change. In 2015, the Sendai Framework for Disaster Risk Reduction (SFDRR) and the Sustainable Development Goals (SDGs) were adopted. Both agreements underscore the importance of climate change adaptation. In addition, climate change adaptation has also grown in importance in the framework of other international organisations and multilateral agreements, such as the Organisation for Economic Cooperation and Development (OECD) and the G7 and G20 meetings.

7.2 Climate models, projections and scenarios

This chapter largely presents results of simulation calculations made on the basis of a climate protection scenario (RCP2.6) and a business-as-usual scenario (RCP8.5) of IPCC AR 5 from 2014. The climate protection scenario (RCP2.6) is based on assumptions in keeping with the political 2-degree upper limit. For this purpose, a scenario development is assumed that involves very sharp and very rapid reductions of GHG emissions with respect to the current situation. The maximum value of the radiative forcing (3.0 W/m²) is reached before the year 2050. From then on, it sinks continuously, to a value of 2.6 W/m² in 2100.

The business-as-usual scenario (RCP8.5) describes a world in which the energy system is based primarily on burning of fossil coal reserves. The GHG emissions in that scenario, with respect to today, increase, in connection with a continual increase of the radiative forcing, until the year 2100. For comparison purposes, an additional scenario is mentioned in the text, the SRES scenario A1B (with regard to more-recent scenarios, see the most-recent IPCC reports – from 2021 (working group 1) and 2022 (working group 2; www.ipcc.ch). It describes a world with strong economic growth and a population increase until the middle of the century that is then followed by a decrease. That is the scenario on which the climate-projection calculations of the 4th IPCC Assessment Report are based.

For Germany, simulations with a spatial grid width of 5 km x 5 km are currently available. For the present report, the results of 32 climate projections have been used that cover the period 1971 to 2100. The regional climate projections used represent the DWD reference ensemble. It serves as the basis for all other evaluations. For calculation of the difference between the current state and the future state, two 30-year time periods are used for each state. An average state is calculated for each time period. The reference period for the observed climate consists of the years 1971 through 2000, from the models. For the future, two time periods are analysed. In the following, they are referred to as the short-term ("middle of the century") and long-term ("end of the century") planning horizons. The short-term planning horizon describes the average state in the years 2031 to 2060. The years 2071 to 2100 serve as the basis for the long-term planning horizon. The future changes are given as a mean value and a range. The range is described in terms of the lowest and the highest change values in the available data sets[179].

7.2.1 Temperature

From 1881 to 2021, Germany has warmed by about 1.6 degrees. In keeping with this trend, the numbers of cold and very cold days have decreased, and the numbers of warm and very warm days have increased.

Further temperature increases can be expected in Germany. For the short-term planning horizon (2031–2060), the increase amounts to an average of about 1.1 or 1.9 °C (median of the ensembles of the two scenarios). The difference between the changes projected by the climate projections (climate protection scenario and business-as-usual scenario) is small. The range of the results lies between 0.8 and 2.6 °C. The warming is somewhat more pronounced in southern Germany. The temperature development for the long-term planning horizon depends strongly on what scenario is chosen. On the basis of the climate protection scenario, an increase of 1.1 °C can expected. The stabilisation at the level of the short-term planning horizon is achieved via the very sharp reduction – in the meaning as defined for the scenarios – of GHG emissions. Hardly any regional differences occur. Under the conditions of the business-as-usual scenario, the warming amounts to an average of about 3.9 °C. The range of the results lies between 2.8 and 5.2 °C. The warming is somewhat more pronounced in southern regions.

7.2.1.1 Regional differences

In the Alps in particular, the projected warming rates, for both the climate protection scenario and the business-as-usual scenario, are even higher than those projected for Germany as a whole. In this case, the change for the short-term planning horizon amounts to between +1.2 °C (climate protection scenario) and +2.1 °C (business-as-usual scenario), with respect to the reference period, 1971–2000. For the long-term planning horizon, average warming rates between 1.1 °C (climate protection scenario) and 4.5 °C (business-as-usual scenario) are projected.
In the coastal region of the northwest and northeast German plain, the changes projected for the long-term planning horizon are somewhat below the average values. In this case, average warming rates between 1.1 °C (climate protection scenario) and 3.7 °C (business-as-usual scenario) are projected.

[179] German Meteorological Service (Deutscher Wetterdienst 2022)

7.2.1.2 Seasonal differences

The warming is similarly pronounced throughout the seasons, with the exception of spring, when it is less pronounced. The temperature increase is accompanied by a marked increase in extreme temperatures. Low-temperature extremes decrease sharply, and high-temperature extremes increase sharply. The frequency of heat waves increases as a result.
In all seasons, the warming in the Alps and the Alpine foreland is more strongly pronounced than the warming for Germany as a whole. The winter warming in the long-term planning horizon, at an average of 4.0 °C (business-as-usual scenario), is considerably above the warming rates projected for Germany as a whole, which average 3.9 °C (business-as-usual scenario)

7.2.2 Precipitation

Precipitation quantities increased in the period from 1881 through 2021. This is especially true in the winter and spring. On an annual-total basis, the increase amounts to an average of 8 percent. By contrast, the changes in the numbers of days with at least 10 litres of precipitation per square meter are hardly noticeable.

In the short-term planning horizon (2031–2060), Germany's average annual total precipitation is not expected to change. A 5% average % increase in the average annual precipitation is calculated. The differences between the scenarios are small. The range of the results lies between a change of −5 % and a change of +14 %. The changes are about equally pronounced in all parts of Germany's territory. In general, it must be noted that a modelled change below 10 % cannot be distinguished from the natural climate variability. This threshold applies to all of the following values**.**

7.2.2.1 Regional differences

In the long-term planning horizon (2071–2100), and in the business-as-usual scenario, an +8 % increase in annual precipitation is expected for Germany. The range of the results lies between −15 % and +19 %. The changes will be about equally pronounced in all parts of Germany's territory. With regard to the change in the number of days with at least 20 mm of precipitation per day, an increase is expected for all regions, both in the short-term planning horizon and in the long-term planning horizon. Only in the Alps region, some models project a decrease in the number of such days. A less-pronounced increase is projected for days with precipitation of 30 mm or more. For strong-precipitation events, however, the range within the ensemble is very large in some cases, meaning that the results are not reliable. Regional differences in the changes in the average annual total precipitation are not pronounced at all.

7.2.2.2 Seasonal differences

For the short-term planning horizon, 2031–2060, and with use of the aforementioned RCP scenarios for winter, average increases of +10 % in precipitation quantities are calculated. For summer months, it is not possible to make reliable trend forecasts. The range of the results ranges from small increases to a slight decrease. In the spring and autumn, average-precipitation-quantity increases of +3 % (autumn) and +8 % (spring) emerge in this planning horizon. In the spring and in the fall, the change in the long-term planning horizon (2071–2100) can amount to +1 to +14 %, while the change in the winter can be up to +17 %. For summer months, in this planning horizon decreases between -2 % in the climate protection scenario (±0 %) and −6 % in the business-as-usual scenario are calculated. The range for the summer, in the business-as-usual scenario, ranges between an increase of +12 % and a decrease of −60 %. In individual regions, the ranges for the summer results are also large, so they do not seem to be particularly reliable. The results of the business-as-usual scenario differ from those

of the climate projections used to date, which are based on the SRES scenario A1B. In the long-term planning horizon, the business-as-usual scenario does not exhibit the large decreases in summer rainfall that are described in the SRES scenario A1B.

7.2.3 Sea levels

Rising sea levels are also a result of anthropogenic climate change. In addition to worldwide melting of glaciers and ice sheets, the causes include thermal expansion of seas and oceans as they warm.

In Cuxhaven, for example, the relative sea level has already risen by about 40 centimetres since the middle of the 19th century (while the German North Sea coast has been sinking locally by about 0.1 cm per year, as an after-effect of the last ice age). At the gauge in Travemünde, the increase amounts to about 25 centimetres. The consequences of this sea-level rise include higher storm surges.

The relative sea-level rise in the North Sea and Baltic Sea, until the end of the 21st century, can be taken from the SSP1-2.6 and SSP5-8.5 scenarios of the IPCC AR 6 Assessment for sea-level rises. The projected rises for German cities, by the end of the century, are about the same along the North Sea and the Baltic Sea. In the SSP1-2.6 scenario for Cuxhaven, for example, a rise of 0.51m is projected, while for Travemünde a rise of 0.5m is projected. In the SSP5-8.5 scenario for Cuxhaven, a rise of 0.51m is projected, while for Travemünde a rise of 0.5m is projected.

7.3 Climate impacts, vulnerabilities and climate hazards

7.3.1 Observed impacts of climate change

While in Germany the temperature warmed by an average of 0.11 °C per decade during the period 1881-2019, the warming rate in the years 1970-2019 was 0.37 °C per decade. This means that warming has accelerated considerably in recent decades. For example, in the most recent decade, 2011-2020, the temperature anomaly with respect to the long-term average for 1891-1920 was a full 2 degrees, after having been 1.4 degrees in the previous decade. The observed accelerated warming also manifests itself very strongly in extremes such as the number and intensity of heat waves. The effects it leads to include greater health risks, associated with heat stress.[180]

Unusually high summer temperatures in three successive years – 2018 through 2020 – have led to a marked increase in numbers of deaths. The unusually long heat wave in 2018 (7.3 weeks long, in the average for all German Länder) resulted in about 8,700 heat-related deaths. That figure is of the same order of magnitude as the corresponding figures for the hot years 1994 and 2003 (10,100 and 9,500 deaths, respectively). For the years 2019 and 2020, about 6,900 and 3,700 such deaths are estimated.

The rising temperatures have led to shifts in seasons and vegetation periods. The duration of the vegetation period increased from 222 days (1951-1981) to 232 days (1988-2017). Animal and plant and animal species from warmer regions of the globe have been

[180] German Environment Agency (Umweltbundesamt 2019): Pressemitteilung des Umweltbundesamtes zur Veröffentlichung des Monitoringberichts der Bundesregierung (45/2019). At: https://www.umweltbundesamt.de/presse/pressemitteilungen/klimawandel-in-deutschland-neuer-monitoringbericht [last checked on 11 Oct. 2022]

spreading; for example, sardines and anchovies have appeared in the North Sea, and the (Asian) tiger mosquito has been spreading on land. That mosquito is known to be a carrier of diseases that were not previously known to have been transmitted in Germany, such as Chikungunya fever and dengue fever.

Water supplies are also being affected by climate change: In the last ten years, low groundwater levels have occurred more and more frequently, and some municipalities have already experienced water-supply problems as a result. Increasing dry periods, and more-frequent (extremely) low water levels in rivers, stress ecosystems, lead to restrictions for shipping and reduce the quantities of cooling water available to power plants and industry. In the last 50 years, the available water in agricultural soils has decreased considerably. In 2018, heat and drought caused damages of 700 million euro in agriculture.

Global warming also affects the economy, since it depends on having functioning traffic routes (roads, waterways). Such infrastructures are vulnerable especially to extreme weather events such as storms and torrential rainfall – or heat and drought.

In 2018, storms and heavy rainfall led to insurance claims of about 3.1 billion euro, for damage to houses, vehicles, household goods, commerce, industry and agriculture. According to the insurance industry, 2018 was one of the four worst storm years of the last 20 years.

7.3.2 Future climate impacts and climate hazards

In connection with the German Strategy for Adaptation to Climate Change (DAS), the federal government is planning to carry out cross-cutting vulnerability and risk analyses at six-year intervals, with a view to refining the DAS and taking account of new challenges and new scientific findings. In 2015, a vulnerability analysis (VA 2015) was published. In 2021, a climate-impacts and risk analysis for Germany (KWRA 2021), which built on that earlier analysis, was published. These analyses show, for different types of climate impacts, and for different regions, what special types of risks, options for adaptation and needs for action apply. They provide information about Germany's overall vulnerability with respect to climate change.

The KWRA 2021 analysis was prepared in the framework of the “Climate change and adaptation” government network (Behördennetzwerk “Klimawandel und Anpassung”), and with input from over 180 experts.[181] It answers the following questions:

1. How will climate change affect nature, our everyday lives, our vital resources, our health and our economy in the future?
2. In what areas can we adapt in ways that will reduce climate risks?
3. Where do we urgently need to act?

As a result, the KWRA 2021 provides an important basis for the further development of the DAS, and it supports the development of concrete measures, such as the federal government's action and measures plans for climate change adaptation. In addition, the KWRA can support a wide range of stakeholders – in particular, decision-makers at the Länder and municipal levels – in climate change adaptation. The methods outlined in the KWRA can serve as a template for regional and local climate-impacts and risk analyses. For this

[181] German Environment Agency (Umweltbundesamt 2022): Klimawirkungs- und Risikoanalyse für Deutschland 2021. URL: https://www.umweltbundesamt.de/publikationen/KWRA-Zusammenfassung

reason, it was used as a basis for preparing methodological recommendations for municipalities and companies.

The KWRA 2021 is based on two future scenarios, one covering the middle of the century (2031 to 2060), and one covering the end of the century (2071 to 2100). Using projections of the IPCC (IPCC 2014), the KWRA 2021 analyses a pessimistic case (referred to in the following as “pronounced climate change”; it includes a +3° C increase in the average annual temperature in Germany by the middle of the century, in comparison to the preindustrial era (1881-1910)), and an optimistic case (referred to in the following as “slight climate change”; it includes a +2.4° C increase in the average annual temperature in Germany by the middle of the century). Where possible, the climate projections were combined with projections of socioeconomic data (until the year 2045, for factors such as population growth, population density, urbanisation), in order to obtain the best-possible estimates of the future impacts.

In the KWRA 2021, over 100 climate impacts – divided into 13 DAS areas of action – were analysed and assessed in terms of the severity of the related climate risks. Both a sectoral and a cross-sectoral analysis was carried out. The latter of two analyses considered 5 system areas (natural systems and resources; economic systems that rely on nature; economic systems that do not rely on nature; infrastructures and buildings; and people and social systems) and their interactions.

Natural systems and resources (such as soil, water, species, ecosystems in the water and on land) and economic systems that rely directly on natural resources (such as fisheries, agriculture and forestry, water-resources management), could be especially affected by the middle of the century. The reasons include such factors as severe decreases in soil moisture and groundwater; poor water quality in seas, rivers and lakes; intensified soil erosion; shifting of cultivation regions; changes in ranges of species and varieties; damages to ecosystems such as forests, wetlands, mountains and coastlines; and the appearance of new types of pests and plant diseases.

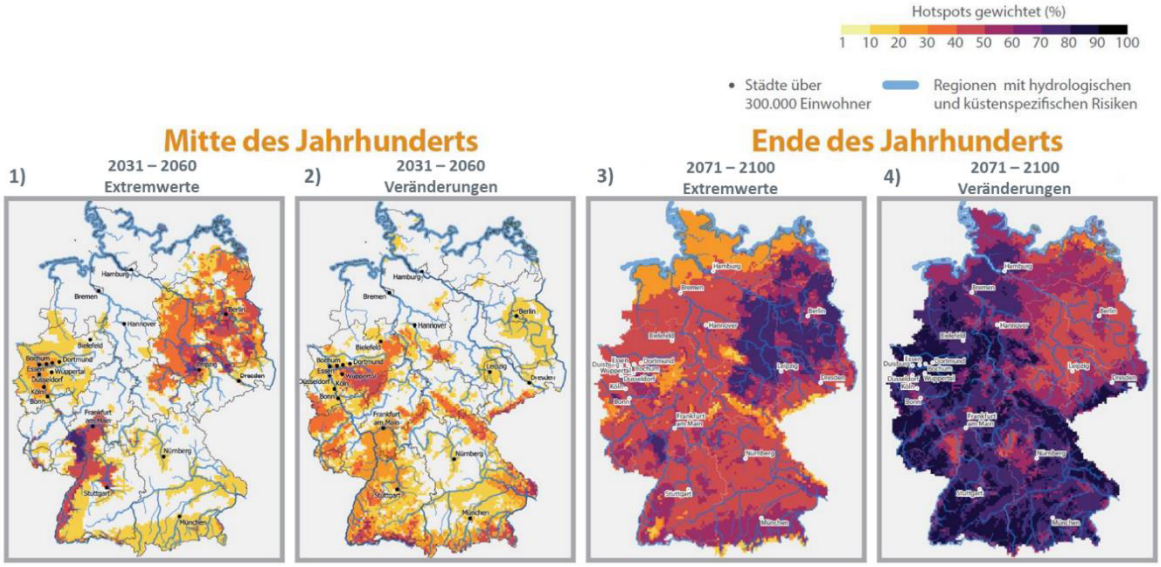
Natural systems and resources are the basis for fisheries, agriculture and forestry and water-resources management – and for many types of human recreation. Protection of natural systems and resources is vitally important in light of the need to prevent negative domino effects on economic systems and on human health – as well as of the need to develop sustainable forms of use.

In the future, humans could find themselves facing increasing heat stresses; more-severe UV-related problems such as skin cancer; and more-frequent occurrences of allergic reactions from airborne allergens; and a number of other climate impacts on their health.

Buildings and infrastructures, such as traffic routes, can also be affected by climate change. For example, they can be damaged by river floods and heavy rainfall. More-frequent, longer-lasting (extremely) low-water events can reduce or interrupt the navigability of waterways.

In the long term, all systems in coastal regions will be affected by rising sea levels. In addition, transnational impacts of climate change, such as interruptions of supply chains, will become more and more significant – and strongly affect even those economic systems that do not depend directly on nature.

Figure 35: Spatial distribution of climatic hot spots in the middle and the end of the century



Maps 1) and 3): Extreme values = Regions that could be affected by especially many climatic extremes; maps 2) and 4): Changes = Regions that could be affected by especially large changes in climate parameters. "100 percent" means that the threshold values are exceeded for all climate parameters considered. The following climate parameters were considered: average annual temperature, number of hot days, number of tropical nights, low annual precipitation, number of dry days, number of days with strong rainfall and the climate parameters' importance for all climate impacts studied.[182]
Database: 85th percentile of the processed Deutscher Wetterdienst reference ensemble v2018 (Brienen et al. 2020) for the RCP8.5 scenario of IPCC AR5, administrative boundaries: Bundesamt für Kartographie und Geodäsie Deutschland, Hydrologie: Joint Research Centre, Städte, Küstenlinie: EuroGeographics. Source: own figure, Eurac Research.

The KWRA 2021 summarises as follows:

- Climate change is becoming more and more visible: Even in the case of slight climate change, all regions in Germany will be affected by further temperature increases, by increases in the numbers of hot and dry days and by heavy rainfall events.
- Differences are seen between different areas: As climate change progresses, Germany's warmest regions will experience an additional temperature increase and additional warming. The country's drier regions will both become hotter and experience more heavy rainfall. In mountain regions, increases in the average temperature, and of heavy rainfall and drought, are expected. Coastal regions will be exposed to hazards resulting from rising sea levels, and areas near rivers will experience more flooding and more low-water events as a result of climate change.
- By the end of the century, the climatic changes could increase markedly in all areas.
- The climate hazards could become considerable already by the middle of the century, especially if climate change is pronounced and no adaptation measures are taken.

[182] Definitions of the climate parameters use are available in the glossary of Deutscher Wetterdienstes (DWD) URL: https://www.dwd.de/DE/service/lexikon/lexikon_node.html

- Natural systems and resources, and economic systems that depend on nature, could already be strongly affected by the middle of the century. The changes in natural systems and resources will affect many other systems.
- If climate change is pronounced, the climate hazards increase significantly by the end of the century. At that point, more than half of the climate impacts studied could lead to large climate hazards, and thereby affect many areas of our lives.

As a key message, the report noted that while all living things and systems in Germany will be affected by climate change, the effects will differ both spatially and chronologically. Climate change especially poses a threat to both a) natural systems and resources, and b) future generations. Protection of natural systems and resources plays a vital role in prevention of domino effects.

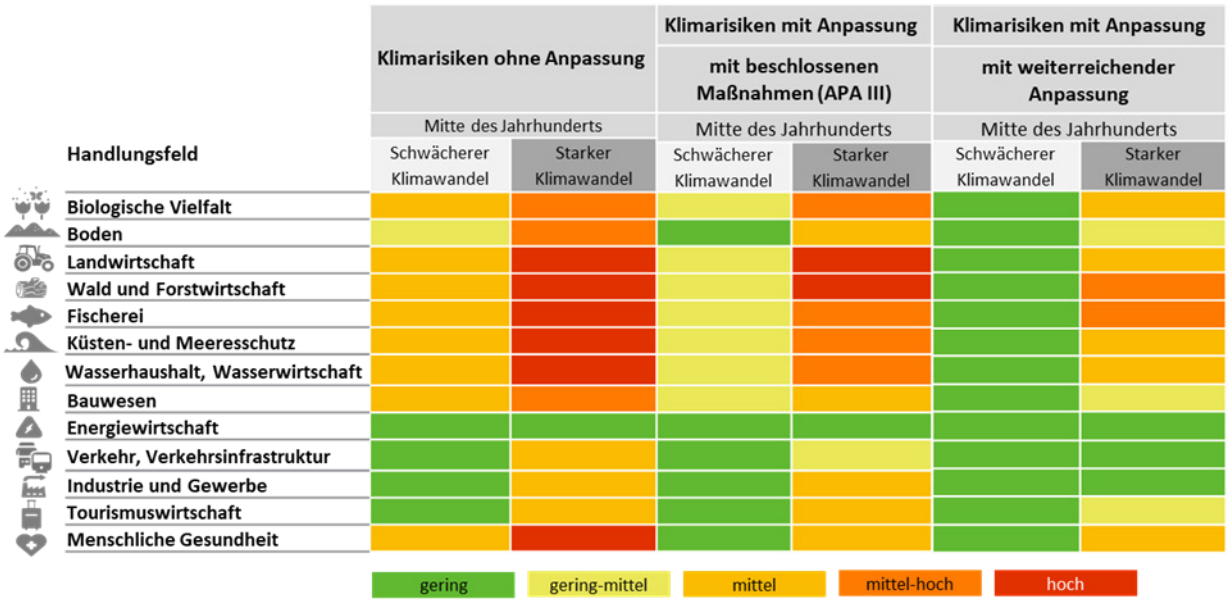
7.3.3 Adaptation capacities, and needs for action

In the KWRA 2021, assessments were carried out, for selected climate impacts, regarding the degree to which adaptation could reduce the climate hazards, and how quickly. For that purpose, a distinction was made between adaptation measures that have already been adopted and more-extensive measures that have not yet been adopted. The adopted adaptation measures were taken from the measures lists of the current federal Action Plan for Adaptation III (APA III), which is part of the Second Progress Report on the German Strategy for Adaptation to Climate Change. The additional (not yet adopted) measures are more extensive than the adopted measures, and they could be implemented under the conditions prevailing today. Also, measures lists were prepared for each climate impact / each area of action studied. A comparison of climate hazards with and without adaptation measures made it possible to derive and characterise needs for action.

With regard to adaptation capacities and the urgency of adaptation, the KWRA 2021 summarised as follows:

- Many climate hazards can be considerably reduced via adaptation measures, especially if climate change proves to be slight. Economic systems that depend on nature should especially strive to use their resources in sustainable, climate-resilient ways.
- If climate change is pronounced, some high risks must be expected. Only with more-extensive measures can such risks be adequately reduced.
- For some climate hazards, the effectiveness of more-extensive measures could be limited. For such scenarios, it seems necessary to develop farther-reaching adaptation measures – i.e. innovative measures that would not be feasible from a current perspective.
- Germany also faces absolute limits on its ability to adapt, i.e. points at which high climate risks can be prevented only via extremely strong climate protection. Such limits would apply to the impacts of climate change on mountain ecosystems, for example.
- For only about one third of all climate impacts considered could adaptation measures begin to take effect in the short term (in less than ten years). Most of the measures involved take considerably longer – in some cases, more than 50 years.
- Immediate action is required especially with regard to high climate risks. The fraction of such risks/impacts for which adaptation measures could take effect in less than ten years is only five percent.

Table 14: Climate risks with and without adaptation, for slight and pronounced climate change, and for 13 areas of action listed in the DAS (middle of the century)



The climate risks were grouped into 5 levels (low, low-medium, medium, medium-high, high) by experts working in the framework of the "Climate change and adaptation" government network (Behördennetzwerk "Klimawandel und Anpassung"), and on the basis of current scientific findings. Source: Own description, adelphi

Table 15: Climate impacts for which action is very urgently required

Handlungsfeld	Klimawirkung
Boden	Bodenerosion durch Wasser
	Wassermangel im Boden
	Bodenerosion durch Wind
	Produktionsfunktion
Biologische Vielfalt	Ausbreitung invasiver Arten
	Schäden an wassergebundenen Habitaten und Feuchtgebieten
	Schäden an Wäldern
Landwirtschaft	Abiotischer Stress (Pflanzen)
	Ertragsausfälle
Wald- und Forstwirtschaft	Hitze- und Trockenstress
	Stress durch Schädlinge / Krankheiten
	Waldbrandrisiko
	Nutzfunktion: Holzertrag
Wasserhaushalt/ -wirtschaft	Gewässertemperatur, Eisbedeckung und biologische Gewässergüte
	Belastung und Versagen von Hochwasserschutzsystemen
	Sturzfluten und Entwässerung
	Grundwasserquantität und -qualität
Küsten- und Meeresschutz	Wasserqualität und Grundwasserversalzung
	Naturräumliche Veränderungen an Küsten
	Beschädigung oder Zerstörung von Siedlung und Infrastruktur an der Küste
	Überlastung der Entwässerungseinrichtungen in überflutungsgefährdeten Gebieten
Fischerei	Verbreitung von Fischarten in Fließgewässern
Verkehr, Verkehrs-infrastruktur	Schiffbarkeit der Binnenschifffahrtsstraßen (Niedrigwasser)
Bauwesen	Schäden an Gebäuden aufgrund von Flusshochwasser
	Vegetation in Siedlungen
	Stadtklima / Wärmeinseln
	Innenraumklima
Industrie und Gewerbe	Beeinträchtigung des Warenverkehrs über Wasserstraßen (Inland)
Menschliche Gesundheit	Hitzebelastung
	Allergische Reaktionen durch luftübertragende Allergene pflanzlicher Herkunft
	UV-bedingte Gesundheitsschädigungen (insb. Hautkrebs)

Source: Own description, adelphi

From a combination of a) duration for adaptation and b) climate risks, 31 climate impacts were identified that call for very urgent action (see table above). These very urgent needs for action have high priority with regard to future adaptation strategies. They were assigned to the following four central challenges:

1. Heat-related risks for health, especially in urban areas, such as areas along the Rhine and Spree rivers.
2. Risks due to drought and low water levels (often in combination with heat), for all systems that use and depend on water. These risks especially apply to rural areas, primarily in the dry regions in eastern Germany and in the west-central part of the country.
3. Risks from heavy rainfall, flash floods and floods, for infrastructures and buildings. Communities in narrow valleys of low mountain ranges have considerably higher risks.
4. Risks due to gradual temperature increases, such as the consequences that sea-level rises will have for natural and nature-using systems. These apply especially along the coasts, in waters, in rural areas and in mountain regions.

The key message of the KWRA 2021 in this regard is that, basically, Germany (still) has many adaptation options available to it. If climate change is very pronounced, the measures already adopted will have to be followed by increasing numbers of additional adaptation measures, some of which will be far-reaching. Some climate risks can be prevented only via strong climate protection, however. Many high climate risks of the future can be reduced only through immediate action now. Many adaptation measures will need several decades to take effect.

From the KWRA 2021, the Interministerial Working Group on Adaptation to Climate Change (IMAA) has derived conclusions for all adaptation actors in Germany.

According to the IMAA, depending on the extent to which climate risks can be reduced via measures (see Table 14), the challenges should be addressed via the following three approaches:

a. Implement known and adopted measures, if the measures can adequately reduce the foreseeable climate risks. Examples include the impacts of low water levels on inland navigation, or of floods on flood protection.
b. Carry out research for the development and dissemination of more-extensive measures, in cases in which only additional measures can be expected to provide substantial risk reduction. This is the case, for example, in connection with the health impacts of heat; the impacts of drought on many water-using and water-dependent systems; or the impacts of gradual temperature increases and sea-level rises on many natural and nature-using systems.
c. Carry out applied research in preparation for far-reaching adaptation as part of a socio-ecological transformation, if the known measures and additional measures cannot adequately reduce the foreseeable climate risks. Examples include the impacts of drought and heat on agriculture and forestry; of heavy rainfall and flash floods on soils, urban areas and drainage systems; or of gradual temperature increases on species compositions and ecosystems.

In the perspective of the IMAA, to reduce climate risks to an acceptable level, all actors and stakeholders in Germany should apply the following principles to their adaptation efforts:

1. Promote ambitious climate change mitigation, which is the central basis for successful climate change adaptation. The more successful climate change mitigation is, worldwide, the more successful climate change adaptation can be. In planning and implementing individual climate-protection

and adaptation measures, take account of conflicts of objectives, synergies and interactions between such measures, to ensure they do not negatively affect each other (example: photovoltaic systems on green roofs).

2. In natural systems and resources, clean up anthropogenic pollution and terminate overuse, in order to strengthen their adaptation capacities (example: reduce pollutant discharges into waters and soils). Protection of natural systems can help prevent negative domino effects and facilitate sustainable forms of use.
3. Take climate risks into account in connection with forward-looking decisions. The impacts of climate change are becoming ever clearer – they now affect almost all areas of life. For successful precaution, therefore, climate risks, such as those identified in the KWRA 2021, need to be taken into account in all relevant planning and decision-making processes at the federal, Länder and municipal levels. Examples include processes related to the maintenance and expansion of infrastructures.
4. View adaptation to climate change as an opportunity to increase sustainability, and strengthen resilience. This means: In implementation of measures, focus especially on measures that benefit natural systems and are socially equitable. For example, use organic-farming practices such as humus management and other forms of sustainable soil management. In addition, prepare additional adaptation measures, including far-reaching measures.
5. In light of the growing and still-increasing urgency, intensify and speed up implementation of adaptation measures, in order to prevent or reduce risks, especially for future generations. Here it must be remembered that some measures can take very long to implement (over 50 years, in some cases). To this end, a reliable financial and legal framework should be created, on all levels, and suitable capacities should be provided.
6. In general, advance climate change adaptation in keeping with the action urgency set forth in the KWRA 2021. The KWRA identified 31 climate impacts with very urgent needs for action and 23 with urgent needs for action. Action is urgently required especially in areas in which many cascading effects could be triggered, where high climate risks already exist, or where high climate risks are expected but adaptation will take a very long time to take effect.

7.4 Adaptation activities – the Federal Action Plan for Adaptation

Federal policy instruments for reducing Germany's vulnerability to climate change

The aforementioned three policy emphases are addressed by the federal government's concrete measures to reduce Germany's vulnerability to climate change. For the next five years, these measures are set forth in the third Action Plan for Adaptation (APA III, 2020), which is described below.

The activities covered by the Action Plan for Adaptation III are assigned to the clusters “water,” “infrastructures,” “land,” “health,” “economy,” and “spatial planning and civil protection.”

Activities of a cross-cutting nature, such as provision of data and information services, or funding of adaptation to climate change, are grouped within the cluster "overarching."

The various clusters' central measures, which are briefly described below, are implemented in the framework of the available budget and finance-plan resources.

Instruments and measures in the "water" cluster

The **National Flood Protection Programme** is being continued, to make it possible to address growing flood risks in a coordinated way, across all Länder. For this purpose, the special framework plan "Preventive Flood Protection" ("Maßnahmen des präventiven Hochwasserschutzes") within the Joint Task for the "Improvement of Agricultural Structures and Coastal Protection," provides federal funding that is combined with Länder co-funding. In addition, the responsible Länder, in keeping with the division of competences set forth in the Basic Law (Grundgesetz; Art. 83 GG), will update the **Flood hazard and risk maps**[183]**,** in the maps' 3rd cycle, by 22 December 2025. In this context, they will also further harmonise the relevant scenarios, hydrological parameters, and methods. The **renaturation of watercourses** that have been developed as waterways and are federally owned, and the renaturation of their riparian meadows, via the **Federal "Germany's Blue Ribbon" programme**, also contributes to flood protection, and it also supports the achievement of "good ecological status" and "good ecological potential"[184] in watercourses. Especially along waterways with modified utilisation for transport, opportunities arise to improve the watercourses' hydromorphology, their ecological permeability and the condition of their riparian meadows.

Climate change can also bring prolonged periods of drought, however (as in 2018 and 2019). Problems then arise via a lack of water availability, and the resulting usage competition (drinking water, irrigation for agriculture, water for extinguishing fires, inland navigation…). To make it possible to resolve **such conflicts of uses in future droughts**, proposals should be prepared for provisions that define drinking water requirements, which may need to be given top priority, and potential hierarchies of water uses, in the case of conflicts of uses. It is also necessary to analyse the risks tied to increasing numbers of low-water events, and to do so on a cross-Länder basis, in order to **provide a basis for systematic and structured procedures, for the federal government and the Länder, for addressing low-water events and droughts.**

Numerous measures are already in place at the Länder level for addressing floods, low-water situations and impacts of sea-level rises. The federal government plans to further expand its cooperation with the Länder in these areas, in the framework of its competence.

Flood hazards grow as the risks of heavy rainfall events increase. Municipalities are responsible for preparedness in this area. The APA III calls for the development of a **Guide to the preparation of hazard and risk maps for local heavy rainfall events**. Preparation of the guide, which should define minimum standards for the preparation of hazard and risk maps, follows up on the LAWA strategy for effective management of heavy rainfall events (cf. Chapter B.4). In addition, the **Potential for decentralised rainwater management in settlement and commercial areas should be reviewed**, with a view to protecting natural water regimes and preventing the need for installation of higher-capacity sewage networks.

[183] Cf. Bund/Länder-Arbeitsgemeinschaft Wasser (LAWA), Empfehlungen zur Aufstellung von Hochwassergefahrenkarten und Hochwasserrisikokarten, available at: https://www.lawa.de/documents/lawa-empfehlungen_aufstellung_hw-gefahrenkarten_und_hw-risikokarten_2_1552298996.pdf

[184] In keeping with the provisions and definition of Directive 2000/60/EC (Water Framework Directive).

Also, **extreme events and damages need to be systematically recorded**. In the interest of better quantification of the extent and frequency of extreme meteorological and hydrological events, and of the damages and environmental impacts they cause, a database documenting (past) events should be prepared in Germany, in keeping with the example of other countries in this regard.

Instruments and measures in the “infrastructures” cluster

In thematic area 1, “**Adapt transport and infrastructure in keeping with climate change and extreme weather events,”** the BMDV Network of Experts is preparing a climate impacts analysis with regard to roads, railways and waterways. The purpose of this analysis is to gain insights into the potential impacts that climatic events and natural hazards can have on federal transport routes.

In addition to causing damages via extreme weather events, climate change can lead to more-frequent heat waves, which can lead to higher interior temperatures in buildings. For this reason, the APA III includes the measure **Integrate aspects of climate-resilient construction (new construction and renovations) in funding programmes**. This is aimed at promoting building designs that are able to counter higher interior temperatures in climate-friendly ways. For example, this can include shading, and evaporative cooling, during periods of summer heat.

The instrument **climate-adapted building construction** is aimed at ensuring that existing findings and knowledge about extreme weather events enter into technical regulations for the maintenance, repair and construction of buildings. This would make it possible, in the framework of funding programmes, to identify key potential hazards at early stages and thereby significantly reduce damages overall. Such efforts are also to include development of assessment guides/tools and/or area-hazard tables.

In the area of responsibility of the Federal Waterways and Shipping Administration (WSV), concrete steps are being taken to systematically integrate climate-change aspects within planning procedures. For this purpose, this “WSV climate-proofing” is integrating data services, guides and training programmes.

Instruments and measures in the “land” cluster

The agricultural sector’s core task (still) is to provide enough food for a growing world population, and to do so sustainably. At the same time, the agriculture and forestry sectors, and fisheries and aquaculture operations, are affected especially strongly by the impacts of climate change (as in 2018 and 2019). In keeping with this insight, in fall 2018 the BMEL began developing an agenda for adaptation of the agriculture and forestry sectors, and fisheries and aquaculture operations, to climate change, in cooperation with the Länder, the BMUV and departmental-research resources. The agenda is based on the DAS guidelines and is thus expected to be integrated within them.

The agenda for adaptation of the agriculture and forestry sectors, and fisheries and aquaculture operations, was adopted by the conference of ministers of agriculture of April 2019. In addition, a measures programme was finalised that comprises both a) measures for short-term response to extreme weather events, and b) measures for long-term adaptation of agriculture and forestry to changing climate conditions. A total of 5 areas of action were defined, and expert groups then prepared catalogues of measures for each area: Crop cultivation (special crops and field crops), forests, animal husbandry, fisheries, aquaculture and overarching thematic areas. The overarching areas include research for breeding of adapted crops and crop varieties; conservation and development of genetic resources; and implementation of climate-adapted, site-adapted crop rotations and variety selections.

Climate change can also endanger the survival of native species. For this reason, the APA III calls for the **development of a nationwide, functioning biotope network**, designed to assure the survival of species and habitats and to enable organisms to adapt geographically to climatic changes. This to be supported via **optimisation of the habitats of climate-sensitive and/or endangered species, with a view to making them more resilient and able to adapt** – for example, by setting aside adequately sized areas with habitat-protection functions. The **Federal Programme for Biological Diversity** serves the purpose of implementing the National Strategy on Biological Diversity, whose "Ecosystem Services" funding priority is expressly aimed at ensuring adaptability to climate change.

In 2019, with a view to improving knowledge about ecosystem changes and rapid declines of biological diversity, the BMBF launched the **"Research Initiative for the Conservation of Biodiversity" (FEdA)**. It is aimed at significantly advancing biodiversity research; consolidating relevant research activities; and making a lasting contribution to efforts to counter the ongoing losses of biological diversity.

The Programme for Protection and Rewetting of Moors and Peatlands (Programme zur Bestandssicherung and Wiedervernässung von Hoch- und Niedermooren) is aimed at addressing the issue of peatland protection by carrying out a number of individual pilot projects on peatland-soil protection, with federal funding. Also, the Climate Action Plan includes measures for development of peat substitutes, and for a peatland-protection programme for agricultural lands, funded with KTF/EKF funds.

Furthermore, a **Climate-impacts and soil-monitoring research network is to be established**. It will be charged with carrying out nationwide surveying and monitoring of the current condition of soils in Germany, including the changes resulting from climate change. To this end, the network will provide convenient access to soil-related measurement data, for researchers and administrators; will coordinate and interconnect activities of operators and users of measurement sites; and will interconnect different measurement-intensity levels.

The effort to **create climate-resilient forests in federally owned forests** calls for stable, structurally rich and location-appropriate development of mixed forests. Such development is to be oriented to the latest research findings. The Forest Climate Fund is used to finance research, development, modelling and communication efforts relative to forests' climate-protection services and their ability to adapt to climate change. It especially emphasises practically oriented projects and transfer of findings into actual practice.

Instruments and measures in the "health" cluster

As a result of climate change, Germany has been experiencing more extreme weather events such as series of heat waves. The heat stresses such events entail are currently one of the largest impacts that climate change is having on human health. For this reason, this area is being given special attention, with suitable measures. The measures include, for example, **Provision of information for the public and health practitioners** and development of **accesses to especially vulnerable population groups** (such as seniors, people with pre-existing conditions, children).

To be able to address heat waves more effectively, the ways in which various relevant instruments function need to be studied, to provide a basis for development of effective measures. To this end, an **inventory, analysis and evaluation of existing heat-wave action plans** is being carried out.

The existing provisions and relevant **state occupational health and safety regulations**, with regard to heat and UV radiation, are being reviewed, and potentially required improvements are being identified. This applies to the Technical Regulations for Workplaces, for

example. In addition, the **Ordinance on Preventive Occupational Health Care (ArbMedVV)** is to be evaluated with regard to the precautions it defines for outdoor work with exposure to intensive natural UV radiation.

This cluster also includes study of pathogenic mechanisms of newly occurring pollen allergens, illustrated with the example of Ambrosia artemisiifolia. In addition, trend analyses relative to imported vector-transmitted infectious diseases in Germany are being carried out. To this end, the Robert Koch Institute (RKI) continually evaluates surveillance data on imported vector-transmitted infectious diseases, at the national level, and publishes important pertinent results.

Also, efforts are to be made to **interlink health-monitoring and environmental-monitoring resources more effectively**, to facilitate monitoring of health-relevant environmental factors, and determination of the origins of problems, in the framework of an integrated, federal-level monitoring system based on existing structures.

Furthermore, **the relevant information and early warning systems will be adapted and expanded**, with proper adaptation of information and delivery channels for all target groups. This instrument also includes the establishment and further development of warning systems for hospitals and care facilities, and the relevant groups of persons, and integration of detection of heat, UV and contaminated air within the pertinent early warning systems.

Instruments and measures in the “economy” cluster

With a view to protecting plants and installations during extreme events, the APA III includes the measure Review of technical regulation for plant safety 310 (precipitation and floods) and 320 (wind, snow and ice), along with updates in light of new climate-change, to be carried out by the Commission on Process Safety (Kommission für Anlagensicherheit).

Climate change is also affecting the German tourism sector. For this reason, the APA III calls for provision of guides for implementation of adaptation measures, such as the development of emergency plans for addressing various extreme weather events. Brief weather events in particular can create hazard situations for tourists and travellers. For example, in the winter of 2018/19, heavy snowfall trapped travellers in winter resorts and accommodations. Consequently, local crisis plans should also take such groups into account.

Instruments and measures in the “spatial planning and civil protection” cluster

In light of the local and regional dimensions of climate change, urban and spatial planning plays a key role in climate change adaptation. For this reason, **climate change adaptation within the context of urban development promotion is being reinforced.** Since 2020, in all programmes, measures for climate change mitigation and climate change adaptation are a mandatory prerequisite for funding, and, as cross-cutting measures, eligible for funding. This includes, for example, measures for improving green infrastructure; energy-related modernisation of buildings; and climate-friendly mobility. This year’s administrative agreement on urban development promotion has additionally tightened the relevant measures: As of 2022, new or revised integrated urban development concepts (ISEKs) must address the issues of climate change mitigation and climate change adaptation. Also, they must derive relevant concrete aims and measures.

Numerous activities in connection with implementation of the measures in the “White Book on Urban Greening” (Weißbuch Stadtgrün (2017)) contribute to climate change mitigation and adaptation. A central role in these efforts is played by funding of urban-greening projects, especially in the framework of the aforementioned urban development promotion; of the federal programme on Adaptation of urban spaces to climate change; of the KfW

programme "Energy-efficient urban refurbishment" ("Energetische Stadtsanierung"); of national urban development projects (federal programme); of the National Climate Protection Initiative; and of the funding programme “Measures for adaptation to the impacts of climate change” (“Maßnahmen zur Anpassung an die Folgen des Klimawandels”). Also, emphasis is being placed on provision of information, via relevant instruments and good practice for climate-resilient urban development, and on research for climate-oriented building and climate-adapted urban development. The guiding principles in this regard include developing an urban blue-green infrastructure that assures good living conditions in cities, binds carbon and reduces the impacts of heavy rainfall, heat and droughts. To this end, the federal government is carrying out research projects, especially in the areas of climate-adapted building, climate-resilient urban redevelopment, water-aware urban development, and improvement of urban natural areas. The key bases for these efforts include detailed surveys and review of the extent and quality of urban green spaces and vegetation, work that is increasingly being carried out with remote-sensing techniques (laser scans, drones, aerial photos, and satellite imagery).

In the framework of the National Water Strategy, the guiding principle of the “Water-Aware City” is to be refined, with a view to promoting sustainable water use in cities. Also, **concepts for decentralised irrigation of urban green space, to guard against drought**, are being improved, and a **sample recommendation** is being prepared. Research in this connection should take account of water types, quantities and quality, in order to rule out the possibility of hazards and stresses for health and the environment.

In addition to the area of spatial planning, civil protection also faces challenges that need to be addressed in the APA III framework. In the framework of the measure **Further development of storm-risk information for the public (Weiterentwicklung der Risikokommunikation zu unwetterbedingten Gefahren mit Bürgerinnen und Bürgern)**, existing information services are being improved – for example, with regard to heat (relates to the health cluster) and heavy rainfall, and integrated within comprehensive risk-communication concepts. Also, **recommendations on cooperation between first responders and volunteers, in the context of extreme weather events,** are being expanded, and a compilation of examples of good practice is being added. This includes the evaluation of experience with citizens’ involvement during storms, and review of ISO-Norm 22319:2017 in Germany. In recent years, the UN’s Sendai Framework for Disaster Risk Reduction (SFDRR) has provided important impetus. A strategic basis for their implementation is currently being prepared. The expected strong synergies between efforts to increase resilience with respect to disasters and efforts in climate change adaptation should serve as added value in the implementation of both strategy processes.

Cross-cutting instruments and measures

With regard to data and information services, the draft of the APA III calls for the continuation and refinement of the German Climate Preparedness Portal (**KLiVO-Portal)** and the **System of services for climate change adaptation (KlimAdapt)**. KlimAdapt, a component of the KLiVo portal, brings together, processes and provides products, services and assessments that support identification and implementation of climate-change adaptation efforts and the further development of the German Strategy for Adaptation to Climate Change (DAS).

For the areas of activity of the German Strategy for Adaptation to Climate Change, the **DAS “Climate and Water” basic service** will provide climatological, oceanographic and hydrological data and advising services. The service provides decision-makers and planners with comprehensive, up-to-date, consistent and quality-assured data for adaptation measures in

Germany. In addition, numerous research projects are listed via which the knowledge base on climate change is to be improved, and climate models on various scale levels are to be refined. This includes, for example, **Funding programmes on the economics of climate change**, and on **Climate resilience via action in cities and regions**, that are aimed at further development of action-oriented knowledge on climate change mitigation and adaptation.

In many cases, not enough research on the climatic influencing factors in the aforementioned thematic areas has been carried out. In particular, further research is needed on the reliability of modelled extremes, in terms of the degree to which they can be modelled, their characteristics and their probability of occurrence. Initial results will be provided in the coming years via, inter alia, new BMBF-funded research programmes (such as ClimXtreme and RegIKlim) relative to the analysis of rare events and refined regional and global climate modelling.

A further measure is the **Lead initiative "Local climate and environmental models for future cities and regions,"** which comprises various components. In the framework of the lead initiative's first component, an urban-climate model will be developed that can take account of all relevant urban-climate processes. In addition, in two further components of the lead initiative, the next generation of climate-information services (Climate Services) will be prepared, and data on a broad spectrum of local environmental aspects will be compiled and linked.

Climate change impacts are to be taken into account, systematically, in existing technical regulations and standards. The measure **Climate-resistant design of existing regulations and technical standards** provides for specifically aimed departmental research, active collaboration in relevant bodies, enshrinement in legal regulations and consideration in federal tendering procedures. In addition, **the need for and practicability of integration of climate change adaptation within specialised laws** is to be reviewed. This is because implementation of DAS, especially at the municipal level, can be reinforced by being integrated within a legal system with binding content and procedural requirements. For this reason, review is needed to determine which specialised laws are relevant in this regard, and which regulatory content needs to be added.

The now-permanent status of the **Government network on climate change and adaptation (Behördennetzwerk Klimawandel und Anpassung)**, mandated by the Interministerial Working Group on Adaptation to Climate Change, supports federal authorities and institutions in implementing the DAS. One departmental research network responsible for DAS implementation is the **BMDV Network of Experts** of the Federal Ministry for Digital and Transport. Its task is to provide practically oriented scientific findings for cross-cutting challenges such as climate change, environmental protection and ageing of infrastructure.

Various funding programmes are aimed at providing a financial framework for climate change adaptation measures. Pursuant to the EU's new, multiannual Financial Framework for the years 2021 to 2027, an increased percentage rate of all funding is to be applied to climate-relevant measures.

The **"Blue Compass" competition,** with which the German Environment Agency (UBA) regularly honours local and regional lighthouse projects on climate change adaptation, is to be continued – subject to the availability of budgetary resources.

Also, a **System for effectiveness analysis of measures and instruments** is to be established, for the purposes of improving targeted selection of DAS measures and policy instruments and facilitating coordination between different specialised strategies.

Nature-based solutions for biodiversity and climate

As the APA III overview shows, many measures for climate change adaptation are nature-based and make use of ecosystem processes. Positive examples of possibilities for adapting to climate change via nature-based solutions (NbS)[185], which effectively and sustainably contribute to the achievement of biodiversity and climate goals, create synergies between biodiversity and climate goals and other development goals, and thereby rely on natural ecosystems, include:

- Renaturation of wetlands and rivers (damage prevention via improved regulation of runoff in connection with floods)
- implementation of blue and green infrastructures, such as parks and green roofs, and lakes and streams, in urban spaces (reduction of heat-island effects in cities, to reduce stresses for people from heat waves, improve air quality, make general positive contributions to human health and well-being, improve environmental quality and living conditions, and improve flood management via the “sponge city” principle)
- In forestry, forest restructuring, to develop climate-resilient mixed forests with (mostly) native tree species, helps ensure that forests can carry out their ecosystem’s functions on a permanent basis.
- Soil-conserving processes in agriculture, which help protect natural soil functions (such as increasing soils’ water-storage capacity) and reduce erosion and compaction.
- Conservation and restoration of natural ecosystems (for example, to increase resilience to climate change impacts)

Efforts in the area of adaptation to climate change should rely more strongly on nature-based solutions, because such solutions provide ecological, economic, social and cultural benefits (cf. in this regard the studies on Germany's natural capital). Many studies have documented a positive cost-benefits relationship.[186] Nature-based solutions also help to strengthen resilience of both society and ecosystems.[187]

The long-term advantages of nature-based solutions, such as a positive cost-benefits relationship, and contributions to the achievement of sustainability goals, are clearly seen at the EU level, which is why, for example, the EU Biodiversity Strategy[188] and the EU Adaptation Strategy[189] set emphases in this area. In Germany, the advantages of nature-based

[185] UNEA 5.2. Resolution 5 “Nature-based Solutions for Sustainable Development” defines nature-based solutions as “actions to protect, conserve, restore, sustainably use and manage natural or modified terrestrial, freshwater, coastal and marine ecosystems which address social, economic and environmental challenges effectively and adaptively, while simultaneously providing human well-being, ecosystem services, resilience and biodiversity benefits’’.
[186] https://www.ufz.de/teebde/
[187] Cf. for example: Seddon N, Chausson A, Berry P, Girardin CAJ, Smith A, Turner B (2020) Understanding the value and limits of nature-based solutions to climate change and other global challenges. In: Philos. Trans. R. Soc. B Biol. Sci. 375. doi:10.1098/rstb.2019.0120; Faivre N, Fritz M, Freitas T, de Boissezon B, Vandewoestijne S (2017) Nature-Based Solutions in the EU: Innovating with nature to address social, economic and environmental challenges. In: Environ. Res. 159, 509–518. doi:10.1016/J.ENVRES.2017.08.032.
[188] https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal/actions-being-taken-eu/eu-biodiversity-strategy-2030_de
[189] https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/12381-EU-Strategy-on-Adaptation-to-Climate-Change/public-consultation

solutions are gradually being recognised and taken into account[190] – inter alia, via the Urban Nature Master Plan (Masterplan Stadtnatur).[191]

7.5 Monitoring und Evaluation

7.5.1 Monitoring of climate change impacts and climate change adaptation

For the German Strategy for Adaptation to Climate Change (DAS), a monitoring system was developed in cooperation with about 300 experts. The first DAS monitoring report was completed in 2015; the second was completed in 2019.[192] Using 105 indicators, it describes climate change impacts that have already been observed and measured, and climate change adaptation measures that have already begun.

The DAS 2019 monitoring report shows the following: Climate change is also occurring in Germany. It manifests itself via both ongoing changes and an increasing frequency of extreme climatic events.

The stronger systems are influenced by people, the more difficult it is to differentiate between climatic effects and effects resulting from changes in utilisation or management methods. For selection of indicators, cause-effect relationships and/or their contributions to adaptation processes, were discussed and weighed by experts.

The term “adaptation” is being used in a broad sense: It also refers to measures that have not been explicitly developed and implemented in the context of climate change adaptation. For inclusion, the deciding factor is whether such measures, in the assessment of experts in the various fields of action involved, support climate change adaptation overall.

The DAS monitoring report is regularly updated. The next report is scheduled for November 2023. It will provide data on the already measurable climate-related changes occurring in the various DAS fields of action that can be taken into account in development of adaptation measures.

7.5.2 Evaluation of the German Strategy for Adaptation to Climate Change

In the 2015 progress report, the federal government called for regular evaluation of the DAS process, to support further development and ongoing optimisation of the processes for climate change adaptation. The results and recommendations emerging from such evaluation have the purpose of highlighting successes of the DAS process, identifying weaknesses and supporting development of recommendations for the refinement of the process. In addition to providing insights about the DAS process (insight function), and reviewing the implementation of measures (review function), evaluations should document the extent to which goals for climate change adaptation have been achieved (legitimation function). Last, but not least, they should also provide support for learning lessons from the process to date (learning function) – for example, in connection with implementation of DAS overall and of individual adaptation measures.

[190] https://www.bmi.bund.de/DE/themen/bauen-wohnen/stadt-wohnen/stadtentwicklung/gruene-stadt/gruene-stadt-node.html

[191] https://www.bmu.de/fileadmin/Daten_BMU/Pools/Broschueren/masterplan_stadtnatur_bf.pdf

[192] German Environment Agency (Umweltbundesamt 2019) – Monitoringbericht 2019 zur Deutschen Anpassungsstrategie an den Klimawandel. URL: https://www.umweltbundesamt.de/publikationen/umweltbundesamt-2019-monitoring-bericht-2019-zur

In the past reporting period, the evaluation methods were developed[193], discussed with relevant stakeholders and adopted by the Interministerial Working Group on Adaptation to Climate Change (IMAA). On the basis of those methods, the IMAA decided to commission an independent evaluation of the German Strategy for Adaptation to Climate Change. Then, it arranged for the evaluation to take place in the framework of a research project of the German Environment Agency[194]. The methodological basis for the evaluation consists of an effects model that was developed especially for the purpose.

The effects model differentiates between a strategic level and an operational level. The strategic level consists of the policy process for development and refinement of the DAS. The operational level consists of the implementation of DAS, with a focus on the Action Plan for Adaptation II. Against this backdrop, five central questions for the evaluation were formulated[195] and then studied, with various methods (interview series, document analysis, survey regarding the status of implementation of APA II, Delphi survey).

The main results and recommendations, at the strategic and operational levels, that were formulated by the independent evaluators can be summarised as follows:

[193] „Evaluierung und Weiterentwicklung der DAS“ (FKZ UFOPLAN 3715 41 106 0), Ergebnisse und Dokumentation siehe Kind, C. et al. (2019) https://www.umweltbundesamt.de/publikationen/methodik-fuer-die-evaluation-der-deutschen

[194] „Durchführung einer Politikanalyse zur Evaluation der Deutschen Anpassungsstrategie an den Klimawandel (DAS) – Politikanalyse DAS“ (FKZ UFOPLAN 3717 48 199 0).
The evaluation was carried out by *Centrum für Evaluation* (CEval, Saarbrücken), in cooperation with *adelphi* (Berlin). The results of the evaluation are recorded in the evaluation report; cf. Gaus et al. (2019) https://www.umweltbundesamt.de/publikationen/politikanalyse-zur-evaluation-der-deutschen

[195] The five central questions for the evaluation were as follows: 1. Is the framework for work on the DAS process suitable (for example, with regard to exchange and coordination, structures for horizontal and vertical cooperation, resources, etc.)? 2. What is the implementation status for APA II? 3. To what extent has climate change adaptation been adequately enshrined (ongoing task and mainstreaming)? 4. To what extent has the DAS process made citizens and businesses more aware of their own responsibility for climate change adaptation (own provisions)? 5. To what extent has the DAS process helped reduce vulnerability to climate change impacts?

Strategic level

The degree of importance being attached to climate change adaptation differs from federal ministry to federal ministry: In some cases, the issue has been strongly enshrined – for example, via establishment of thematically specific specialised departments. In some case, climate change adaptation is not a high priority – for example, because there is little concern about climate change or because the currently available resources do not allow making it a high priority.

The evaluation results support the conclusion that institutionalisation of climate change adaptation needs to be intensified in the ministries, and – in keeping with this conclusion – cooperation between the ministries need to be intensified as well (horizontal integration). Along with this need for intensified interdepartmental cooperation, the evaluation also identified a need for intensifying federal-Länder cooperation and making it more strategically oriented (vertical integration). In light of the interview results, the existing cooperation between the federal government and the Länder is seen as being good but having room for improvement; from the Länder perspective, the legal bases for climate change adaptation need to be strengthened, and the federal government's financial activities in this regard need to be expanded, taking account of federal structures, with a view to improving implementation of measures. The federal government can achieve this aim, for example, by integrating climate change adaptation within federal funding instruments, in order to facilitate investment measures.

If adaptation measures are to be effective, the goals for climate change adaptation have to be clear and specific. The results of the evaluation show that the federal government should formulate the action goals, relative to climate change adaptation, more clearly and specifically in the strategy documents (such as progress reports). While the goals formulated in the DAS, and in the 2015 progress report (reduce vulnerability to climate change, increase adaptation capacities), do provide general orientation, they make it difficult to review the extent to which the goals have been achieved or can be achieved – the goals have been formulated too unspecifically. In this connection, the evaluation shows that the DAS documents should be more forward-looking; i.e., they should also formulate specific guiding principles or goal systems for climate change adaptation.

Participation of both state and non-state stakeholders is one of the keys to making the need for climate change adaptation more widely accepted in society. The following was determined in the evaluation: While participation processes were carried out in the various ministries and departments, such processes have not been comprehensively and systematically enshrined in DAS implementation and refinement. The DAS evaluation recommended that participation and consultation processes be expanded, with a view to making broader segments of society aware of the need for climate change adaptation, and in order to take social aspects and equitability issues into account in connection with climate change adaptation.

Operational level

Measures for climate change adaptation have the greatest effect when they are applied to the areas in which the needs for action are greatest. The evaluation showed that this is not always occurring. As a result, it recommended formally upholding and enshrining the direct connections between 1. strong requirements for action, 2. systematic selection of adaptation measures that precisely fit the requirements, and 3. prioritisation of such measures. Planning of measures needs to focus on climate impacts calling for an urgent response, and it needs to be more strongly oriented to the actual implementation of measures. This

means that persons/agencies/entities responsible for measures have to be enabled to implement them (see above: facilitating access to investment funding). The DAS evaluation also recommended that the federal government's role as a model, in connection with implementation of measures, be strengthened. For example, this could be achieved by making federally owned buildings, properties and infrastructures climate-resilient. This would strengthen the federal government's role as a driving force.

In many cases, the effectiveness of measures for climate change adaptation is directly "visible" – as in the example of the effects of blue and green infrastructures in reducing heat-island effects in densely populated regions / major cities. In some cases, measures take a long time to become effective. With many measures of APA II, it is currently (methodologically) difficult to draw any reliable conclusions about their effectiveness. For this reason, the evaluation recommends improving estimates of the effectiveness of measures and of the DAS as a whole.

One important component of the DAS is that it calls for improvements in citizens' and companies' own provisions and precautions. The evaluation shows that while this is already occurring to some extent, awareness of the need to take one's own measures (in the sense of personal provision) needs to be improved – for example, through more-comprehensive awareness measures and through services (including services provided by the federal government) – with a view to enabling citizens and companies to identify and implement measures on their own. With these things in mind, the DAS funding programme, which has been in place since 2011, and is being used by some municipalities, should attempt to reach companies and citizens more effectively.

7.5.3 Evaluation of adaptation activities to date

Status of implementation of APA II (from 2015): Three-fourths of the total of 147 measures under APA II have already been implemented or are currently being implemented.[196] One fourth of the measures are either being prepared or have not yet been implemented. In the survey in the evaluation framework, one third of the measures were listed as still in progress. Somewhat less than one fourth of the measures were referred to as "ongoing tasks" – which reflects the fact that APA II and the DAS progress report of 2015 mark a transition from project-style, temporary measures to long-term measures.

According to the survey carried out within the evaluation, the factors determining success in implementation of measures[197] include: the availability of relevant previous work, such as from a previous project; the degree to which measures are oriented to actual practice and needs; networking of stakeholders and integration of relevant/competent stakeholders; acceptance/agreement on the part of the public; availability of resources; and good communication on the part of participants. The reasons given for delays in implementation of measures, or for failures to implement measures at all, included[198]: staffing shortages, poor communication and coordination, and a lack of data. Also, some measures were

[196] The APA II implementation status reported here was determined via the DAS evaluation (cf. Chapter B.5 and Bundesregierung 2015, p. 8). Methodologically, this was carried out with the "APA status tool" (cf. the evaluation report, pp. 69-72), and the results were supplemented with information about success factors and obstacles in implementation of measures for climate change adaptation. That information was obtained via interviews with the persons responsible for the APA II measures. The results reported here reflect the status as of May 2018.

[197] In connection with the implementation status of the APA II measures, the APA status tool also asked what the success factors for implementation of measures were. For a total of 39 measures, information about success factors in connection with implementation was provided.

[198] In a total of 29 cases, delays in implementing APA II measures occurred, or the measures were not carried out at all. Often, reasons for such delays were given in the APA status tool.

postponed, or not carried out at all, due to changes in priorities. The analysis of the APA II implementation status also shows that measures for climate change adaptation need to focus more systematically on areas in which action is urgently needed.[199]

7.5.4 Summary and outlook

In light of the second DAS progress report, dating from 2020, and the coalition agreement for the current federal government, significant measures and instruments for climate change adaptation are already being implemented in the framework of the available budget, such as the following:

- Start of the nationwide process for identification of concrete, measurable goals for climate change adaptation.
- Continuation of work on a federal law on climate change adaptation that is to be adopted in the current legislative period.
- Intensive federal-Länder process for joint financing of climate change adaptation.
- Adaptation of national soil conservation laws in keeping with the challenge of climate change.
- Establishment of a National Soil Monitoring Center within the German Environment Agency (UBA).
- Adoption of an “Immediate-action programme on climate change adaptation” of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection in March 2022, with the emphases “Funding and competence-building – local advising – better networking.” In this regard, the “Zentrum KlimaAnpassung” (“Centre for Climate Adaptation”) establishment in July 2021 plays a prominent role.
- Stabilisation and expansion of the programmes “Measures for climate change adaptation” and “Climate change adaptation in social institutions.”
- Initiation and execution of the action programme “Natural Climate Protection” (“Natürlicher Klimaschutz”), which supports both climate change mitigation and climate change adaptation.
- In November 2020, the Federal Ministry for Digital and Transport (BMDV), the DAS ”Climate and Water” basic service was established at Deutscher Wetterdienst (DWD, coordination), the Federal Institute of Hydrology (BfG), the Federal Maritime and Hydrographic Agency (BSH) and the Federal Waterways Engineering and Research Institute (BAW).

Attention is called to the fact that all measures that are mentioned in the National Communication and that the federal government has announced and approved are subject to the condition that they receive financing – and thus can be implemented only if they receive the necessary financing in the relevant budget section or policy area. The present report and the federal government's official position are without prejudice to either current or future budget negotiations.

[199] The evaluation report notes, in detail, which APA II measures and instruments directly and systematically address climate impacts for which action is urgently required – and which ones do not.

8 Research and systematic observation

8.1 Fundamental orientation, financing and research landscape

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 will 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 climate research and research on 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 about the research landscape are given below). The German Committee Future Earth (DKN Future Earth) works as an advisory body on international developments and activities in connection with the global research initiative “Future Earth.”

The supports sustainability research in various fields, including environmental aspects of sustainability, primarily in the Research for Sustainable Development strategy (FONA). The FONA strategy implements Germany’s National Sustainable Development Strategy and the federal government's upcoming “Future Strategy on Research and Innovation.” They contribute to achieving the emission reduction targets, and to the targets for expanding the use of renewables and increasing energy efficiency.

With its upcoming “Future Strategy on Research and Innovation” (“Zukunftsstrategie Forschung und Innovation”), Germany will be able to retain and expand its position as a technology leader in the areas of climate change mitigation, climate change adaptation, sustainable resource management and innovative environmental and energy technologies. Here, too, FONA 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 7thEnergy Research Programme. The ministries responsible for this programme are the Federal Ministry for Economic Affairs and Climate Action (BMWK), 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 the future energy supply and to develop those technologies. The 7th. 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 Energiewende energy system transformation. The funding for key areas – energy efficiency and renewable energy – places the emphasis on technologies used to generate electricity with wind and photovoltaic systems; on increasing the share of renewables in the heating sector; on energy-optimised buildings and neighbourhoods; and on 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 for Digital and Transport (BMDV) funds application-oriented research and development for climate change mitigation, and transport-sector sustainability, in the areas of electromobility, hydrogen fuel cells and production of renewables-based fuels. Support is provided for development and demonstration projects aimed at enabling such technologies to contribute significantly to GHG-emissions reduction in the medium term. The requirements resulting from the aims of sustainability, climate change mitigation and climate change adaptation manifest themselves in the following selection of institutions carrying out ministerial-research tasks of the BMDV:

- Federal Highway Research Institute (BaSt): In this context, the area of construction is of special interest. The stringent durability requirements applying to roads have to be brought into line with the need to use resources sustainably and the need to reduce GHG emissions. A second aspect has to do with consideration of new developments in the area of available construction materials and construction procedures. The special challenges that present themselves in this area include the challenges of meeting both transport needs and criteria for nature and environmental conservation, noise protection and biodiversity protection; addressing road-capacity and infrastructure-age issues; and developing new, climate-friendly mobility concepts. The overall aim is to provide a requirements-oriented, available and resilient infrastructure, and to make lasting improvements in the infrastructure. Research into strategies for energy-efficient transport infrastructure also contributes to GHG emissions reductions.
- Deutscher Wetterdienst (DWD): Improvement of observation, analysis and modelling of weather, climate and chemical composition of the atmosphere, on various spatial and chronological scales; studies of weather and climate processes with regard to applications – in areas such as protection of traffic routes, disaster management, civil protection, environmental protection, renewable energies, and the German Strategy for Adaptation to Climate Change.
- Federal Waterways Engineering and Research Institute (BAW): Development and assessment of sustainable construction processes and construction materials
- Federal Institute of Hydrology (BfG): Environmentally compatible and resilient transport infrastructure; determination and assessment of biodiversity; ecologically oriented maintenance and renaturation
- Federal Maritime and Hydrographic Agency (BSH): Studies of trends and changes in the marine climate of the North Sea and Baltic Sea, and of the Atlantic Ocean, and development of forward-looking technologies for safe, sustainable ship operations
- German Centre for Rail Traffic Research at the Federal Railway Authority (DZSF/EBA): Study of various aspects of expansion of rail traffic – for example, expansions via reactivation of track sections – and studies on the resilience of rail traffic with respect to natural hazards

In the BMDV Expert Network, departmental research institutions and the DWD (a specialist agency of the BMDV) carry out joint, cross-agency studies within projects focussing on

climate action in the transport sector. For example, they assess the potential for installation of renewable-energy infrastructure along transport infrastructure.

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, organic farming, animal husbandry, crop-cultivation strategy, protein-crop strategy, international forestry research and global food and nutrition security research. With the findings gained from their research projects, the BMEL's sectoral research institutes support climate change mitigation in agriculture, horticulture, forestry, fisheries and the food industry.

The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) 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 evaluation of social, economic and technological trends. This is significant in that 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 BMUV is to investigate ways in which societal 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.

Climate impacts research, which studies the interactions between climate changes, natural systems and human society (socioeconomic systems), provides the scientific foundations for concrete measures for adaptation to climate changes. 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. Often, observation data do not provide adequate resolution. 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 funded by the BMBF and the DFG, or carried out by research institutions – such as the Max Planck Institute for Meteorology and the Helmholtz Climate Initiative REKLIM, a consortium of eight research centres within the Helmholtz Association.

To be able to better assess and quantify the scope of future climate trends, the BMBF is focussing increasingly on developing high-resolution climate and Earth-system models that, in connection with the availability of suitable supercomputers, open up new possibilities. To this end, the BMBF has launched "WarmWorld," a funding measure aimed at the development of a new, extremely high-resolution, global climate model, and of an innovative reorientation of climate projections. Along with that effort, and also with a view to identifying the full scope of future climate trends, ensemble analyses continue to be carried out, for

derivation of probability forecasts on the basis of all available regional climate simulations for Germany, taking account of the IPCC RCP (representative concentration pathways) scenarios.

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).

The mission of the Helmholtz Association of German Research Centres (HGF) is to pursue the government's and society's long-term research objectives and preserve and enhance the resources that sustain human life. To do this, it identifies and explores issues concerning society, science and industry 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)
- GEOMAR Helmholtz Centre for Ocean Research Kiel
- Forschungszentrum Jülich (FZJ; Jülich Research Centre)
- Karlsruhe Institute of Technology (KIT)
- Helmholtz Centre Potsdam – German Research Centre for Geosciences (GFZ)
- Helmholtz Centre Hereon (Hereon)

Helmholtz Centre for Environmental Research Leipzig – UFZ

The Helmholtz Association's Earth and Environment research field examines the basic functions of the Earth as a system, and the basic interactions between nature and society, in the framework of an overarching programme, "Changing Earth – Sustaining our Future," which is divided into nine topics:

- The Atmosphere in Global Change
- Ocean and Cryosphere in Climate
- Restless Earth – Towards Forecasting Geohazards
- Coastal Zones at a Time of Global Change
- Landscapes of the Future
- Marine and Polar Life
- Towards a Sustainable Bioeconomy
- Georesources
- Healthy Planet

As a result, the programme will study the natural bases for life – on the land surface, in the oceans and in the polar regions – in order to illuminate pathways into a sustainable future, and do so on the basis of sound knowledge about the Earth as a system, of innovative technologies, of well-conceived strategies and of recommendations for action on the part of policymakers.

The seven Helmholtz Centres listed above are working together to gain insights into the complex interrelationships between processes at work on planet Earth. What is causing global environmental changes, and what impacts are the changes having? How can we use our natural resources sustainably? How can we improve our protection against disasters, and against natural hazards such as droughts, torrential rain, storms, floods and earthquakes? The programme is aimed at developing solutions and strategies that address the following issues: how human beings can best adapt to changed environmental conditions; how we can diminish global threats such as climate change; and the impacts that such threats could have if they materialise – not only on the environment, but also on our societies and economies.

The research area is working to interconnect the findings that are resulting from such work, and to advance cooperation between the Helmholtz Centres and national and international partners. A synthesis and communication platform has been established, to enable findings from the research to receive public attention and be able to influence societal developments and trends.

The 97 institutes of the Leibniz Association (WGL) devote their research to issues of societal, economic and ecological importance. Numerous Leibniz institutes, working in keeping with the Leibniz motto, “Theoria cum praxi,” enhance the German climate-research landscape, especially in sections “B – Economics, Social Sciences, Spatial Research,” “C – Life Sciences” and “E – Environmental Sciences”: They bring together 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 (TROPOS) 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 (RWI), 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: analysis of individual and collective behaviour, markets and institutions, especially with regard to energy and climate policy
- Leibniz Institute for the Analysis of Biodiversity Change (LIB),

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 include 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, Kaiserlautern
- 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 a total of about 3,500 employees, as of 1 July 2020) use varying shares of their capacity, with different points of emphasis, to conduct research into climate change mitigation and/or adaptation to climate change, in the agriculture and food sector:

- 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, and on 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. On the data side of this link, the German government is emphasising continuous, long-term observation of processes in the atmosphere and the oceans and on land, to ensure that measurement data are meaningful. In addition, it is facilitating detailed investigation of key processes, such as that carried out by the modern

research aircraft HALO and POLAR 5, the 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 the Federal Ministry of Education and Research (BMBF). These include the following: World Climate Research Programme (WCRP), International Geosphere-Biosphere

Programme (IGBP), Global Earth Observation System of Systems (GEOSS), Global Climate Observing System (GCOS), EU (Copernicus), UN marine policy (for example, RIO+20, UN Agenda 2030, UN Ocean Decade).

Germany is already the leading European participant in space-based climate research and Earth observation: German missions such as the TerraSAR-X and TanDEM-X radar satellites monitor global phenomena such as the state of the polar ice caps, of major continental glaciers, and of deserts, rain forests and oceans. The EnMAP (Environmental Mapping) satellite, which has been in orbit since 1 April 2022, is an optical satellite that will provide complementary observations.

Since 2002, the German-American GRACE and GRACE Follow-On satellite missions have provided high-precision data on the Earth's gravity field. Such data is used, for example, to determine sea-level changes, and mass changes in land ice (such as glaciers and polar ice caps). GRACE satellites also provide information about seasonal variations in continental hydrological cycles, about long-wave ocean circulation and about heat transport from the equator to the poles. As a result, they are able to take account of changes due to climate change. To enable the important GRACE time series to continue, a third GRACE mission (GRACE-I) is now being prepared.

In cooperation with NASA, the GRACE-I follow-on mission will provide such continuity until well after 2030.

Starting in 2027, MERLIN, a Franco-German satellite project, will measure global distribution of methane, a highly potent greenhouse gas, in the atmosphere. Also, as of 2026 a DLR small-satellite project (CO2Image) will observe point sources of carbon dioxide and methane. Its measurements of small and medium-sized anthropogenic sources will complement the data provided by global monitoring systems such as Copernicus. ESA's Climate Change Initiative (CCI), an effort designed to monitor climate change, is making significant contributions to the consistency of global climate data. A follow-on programme, CLIMATE-SPACE, will also keep track of climate "tipping points." Germany's contributions to this this European programme are in keeping with its GNP (at least). The European MeteoSat and METOP weather-satellite systems continue to be improved. Under Franco-German leadership, their second (METOP-SG) and third generations (METEOSAT Third Generation, MTG) are being developed. They will be launched in 2022 and 2023, respectively, and, beginning in about 2023 or 2024, will continue the observations carried out by their predecessor generation. Copernicus (EU), the European Earth observation system, also contributes significantly to monitoring of the climate system and to forecasting of climate impacts. Current planning for the launch of the first generation of Sentinel satellites have a time frame until 2030. Expanded missions with dedicated climate observation, such as CO2M (CO_2 and methane monitoring), and CHIME (land surface), will expand the portfolio as of 2025 and operate until well in the 2030s. Their climate-relevant data will complement data provided by the EU's already operational services (Copernicus). Establishment of the six special Copernicus services for routine provision of key data products, including products of relevance for climate issues, has been completed, and the programme has moved into the operational phase. Here as well, Germany is playing a leading role in the relevant European alliance. To enhance control of the German contributions, the following actions are being carried out, under the leadership of the Federal Ministry for Digital and Transport (BMDV), for each of the six Copernicus services, which include the Copernicus Land Monitoring Service, Copernicus Marine Environment Monitoring Service, Copernicus Emergency Management Service, Copernicus Atmosphere Monitoring Service, Copernicus Climate Change Service, and Copernicus Security Service: specialised national coordinators are being

appointed, funding measures are being initiated, national Copernicus forums are being carried out and online information services are being provided.[200] The Copernicus Data and Exploitation Platform – Deutschland (CODE-DE) is the national Copernicus access point for satellite data of the Sentinel family and of complementary national satellites, as well as for information products of the Copernicus services. Since 9 March 2017, current data from the Sentinel 1 through 3 and 5P satellites can be accessed online, quickly and easily, via the CODE-DE platform. With the launch of MetOp and MTG, Sentinel-4 and Sentinel-5 have been added to the portfolio. Significantly, on the platform users can both carry out their own analyses and make analysis algorithms available.

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, DWD operates extensive observation networks that 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 strategy (FONA). The strategy aims include: to improve estimation of trends for extreme climate events; to improve climate projections by reducing the uncertainties in the projections; and to carry out comprehensive monitoring of GHG emissions. With regard to the impacts of global warming on the occurrence of extreme climatic events, the BMBF's ClimXtreme funding measure seeks to obtain scientifically sound answers to the following basic questions: (i) Are extreme events already occurring more frequently, as a result of climate change? (ii) Have especially intensive extreme events become more likely as a result of climate change? (iii) How will climate change extreme events in the future, in terms of their intensity, frequency and spatial distribution?

The research initiatives are being complemented by targeted funding of research-oriented and monitoring-oriented infrastructure measures, such as measures for supporting ground-based and airborne measurements of GHG-relevant trace gases. For example, in the ACTRIS (Aerosol, Clouds and Trace gas Research InfraStructure, www.actris.eu) pan-European infrastructure measure, and with Germany's participation, little-studied volatile trace gases, aerosols and clouds, and their influences on air quality and climate, are being studied. Another measure is the Integrated Greenhouse Gas Monitoring System (ITMS), with which a new method – unprecedented in being measurements-based – is being used in order to identify emissions (source strengths) of greenhouse-relevant trace gases. ITMS, therefore, can be seen as an answer to the Paris Agreement of 2015. In addition to its main task of reliably identifying sources, ITMS will also be able to answer questions regarding the impacts of possible source-strength changes on atmospheric concentrations (such as the changes currently occurring as a result of the coronavirus pandemic, or those occurring in the context of permafrost-soil thawing).

By introducing the Integrated Greenhouse Gas Monitoring System for Germany (ITMS), which commenced its operations in 2021, FONA has facilitated measurements-based and model-based determination of the source strengths of greenhouse-relevant trace gases,

[200] www.d-copernicus.de

which makes it possible to objectively measure progress in emissions reductions. In 2022, the COMET field experiment was expanded to include COMET-2, over Canada and the American Arctic. The programme expansion has been very successful. Climate-relevant trace gases, such as methane and CO_2, were registered above a number of different scenarios (oil sands, wetlands, Arctic, etc.), and they are being analyses with the help of complementary satellite data. Data assimilation, a process carried out within numerical weather-forecasting systems, makes it possible to use the totality of data from all observation systems synergistically and optimally. This process is also used in connection with model-based real analyses, in order to obtain consistent descriptions of atmospheric parameters over long periods of time. For the global atmosphere, this is carried out at the European Centre for Medium-Range Weather Forecasts (ECMWF), of which Germany is a Member State. Regional real analyses can achieve spatially higher resolution. This approach is being pursued, in cooperation with Deutsche Wetterdienst (DWD), at DWD's Hans Ertel Centre for Weather Research, which is housed at the University of Bonn. Development work aimed at improving climate forecasts and climate projections is being carried out at various 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. To address climate change, we need technical and societal innovations.

Marine, coastal and polar research is funded in the framework of the federal government's "MARE:N – Coastal, Marine and Polar Research for Sustainability" ("MARE:N – Küsten-, Meeres- und Polarforschung für Nachhaltigkeit"). Precautionary research seeks to address major societal challenges, and to generate useful knowledge relative to the protection and sustainable utilisation of coastal and marine regions. Research in this area is expected to improve our understanding of the world's oceans, help protect vulnerable coastal regions, explore polar regions and carry out supporting research into the potential utilisation of marine resources. The funding priorities include: the oceans as sinks for heat and carbon dioxide; impacts of rising sea levels and climate changes in coastal regions; and impacts of ocean warming, pollution and acidification on biological diversity and on resources available for people.

The Agenda processes "Coastlines in Transition," "Blue Ocean" and "Polar Regions in Transition," which have been developed in cooperation with researchers, and summarized in concept papers, serve as an important basis for funding announcements.

The German Marine Research Alliance (DAM) provides structures for developing specific recommendations for action, for policymakers and society, in the framework of research missions. The first DAM research mission, "Marine Carbon Sinks in Decarbonisation Pathways," is investigating whether, and to what extent, the ocean can play a central, sustainable role in absorbing and storing carbon dioxide from the atmosphere. Taking account of the multiple ways in which German coastal waters are used, and the multiple stress factors they face, the DAM research mission "Protection and Sustainable Use of Marine Areas" is aimed at developing concepts and recommendations for action with regard to various types of uses. A third research mission, focussing on extreme marine events and natural hazards,

will develop a knowledge base for decisions relative to future scenarios and risk assessments.

In light of the many points of contact between many different relevant science and technology disciplines – for example, in coastal research, in utilisation of marine resources, or in addressing of natural hazards – programmes have to be intensively coordinated with "neighbouring" programmes, including BMBF programmes, universities' programmes and programmes of other ministries.

By funding major research institutions, via institutional funding; by funding projects and by funding infrastructure measures such as construction of new ships and operation of research ships, the BMBF and the German Research Foundation (DFG) make significant contributions to the overarching goals of the UN Ocean Decade and to the UN Sustainable Development Goals – especially Goal 14, "Life Below Water."

The BMBF is participating actively in the European Joint Programming Initiative "Healthy and Productive Seas and Oceans," in the EU Partnership "A Climate-Neutral, Sustainable and Productive Blue Economy" and in the EU mission "Restore our Ocean and Waters." By bringing national capacities together with those at the EU level, these measures seek to provide an oceanographic basis for viable, sustainable utilisation of marine resources; for forecasting of climate change's impacts on oceans; and for deriving resulting adaptation strategies.

Under the umbrella of its Johann Heinrich von Thünen Institute / Federal Research Institute for Rural Areas, Forestry and Fisheries, the BMEL maintains three specialised institutes: for Fisheries Ecology, Sea Fisheries and Baltic Sea Fisheries, and with locations in Bremerhaven and Rostock. The institutes, each of which has its own research ship, take part in carrying out monitoring tasks, within international research networks.

The BMDV contributes to marine research via the Federal Maritime and Hydrographic Agency (BSH), with its long-term observations with the MARNET station network; its North Sea surveys; and its (German) participation in the mobile observation system for the world's oceans, within the ARGO programme.

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. Overall, the utilisation pressures on limited water resources will continue to grow sharply, and the requirements pertaining to sustainable water resources management will become tighter and tighter. Since 2021, the research programme "Water: N – Research and Innovation for Sustainability" ("Wasser: N – Forschung und Innovation für Nachhaltigkeit") has been the federal government's framework concept for funding research and innovation in the area of water resources. The Water: N programme addresses six thematic priorities, for which funding announcements are regularly being made. The thematic priorities include "Clean Water," "Intact Ecosystems and Sustainable Development of Water Resources," "Liveable Cities and Regions," "Resource-Efficient Water Cycles," "Protection from Water-Related Extreme Events," and "New Water Culture." In this context, adaptation to climate changes has been identified as an important field of action for

sustainable development in the area of water resources. For Water: N, the BMBF is providing a total of 350 million EUR in funding.

Since 2022, and in the framework of the measure “Extreme Water Events (WaX),” the BMBF has been funding 12 collaborative research projects that are developing strategies for improving management of extreme hydrological events such as torrential rains, floods and droughts. In the process, suitable adaptation strategies are being developed that can limit the impacts of extreme events on the aquatic environment and on people, and that also open up new perspectives for the water-resources sector.

Since 2021, in the funding measure “Water Technologies: Reuse,” 13 collaborative research networks are developing innovative technologies, process concepts and management strategies for resource-efficient, energy-efficient processing, desalination and reuse of water. As a result, the measure is contributing significantly to the reduction of energy requirements and CO_2emissions, while also contributing to increases in water availability.

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 affect land use in most regions of the world. However, we still know too little about how changes in climate actually affect natural and cultivated landscapes. At least partly, that is true 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. In addition, high expectations are being applied to the climate-protection services that could be provided by land use that has been adapted to climate change. That said, the influences of climate change – including higher temperatures, more-extreme summer droughts and increasingly severe extreme weather events – on the climate-protection services of land use have only begun to be studied.

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 CH_4 and N_2O – and therefore to climate change. Furthermore, emissions of NH_3 indirectly interfere with the thermal and material balance of the Earth’s atmosphere: NH_3 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 N_2O. 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 CO_2 emissions that – unlike other CO_2 emissions from agriculture – are not “carbon neutral.”

Within the funding measure “Sustainable Land Management in Subsaharan Africa: Improving Livelihoods through Local Research” (“Nachhaltiges Landmanagement in Subsahara-Afrika: Durch Forschung vor Ort Lebensgrundlagen verbessern”), a total of 4 collaborative research networks are being funded. Their focuses include further development of digital applications such as smart farming, advising apps, e-Learning and decision-support systems. To be sustainable, development of African rural areas must take even-handed account of climatic, ecological, economic and social aspects. Digital tools have a decisive role to play in such development.

By binding CO_2 and serving as carbon sinks, forests and wood play an important role in achieving the federal government's climate targets.

Since 2013, via the Forest Climate Fund (WKF), the BMEL and the BMUV have jointly supported a range of efforts relative to the thematic areas of climate protection in forests and ways of adapting forests to climate change, including research, development and demonstration projects; communication measures; and efforts to promote networking between scientists and stakeholders. Currently, a total of 280 multi-year projects are being funded, with total funding of 113 million euro.

Measures in the WKF framework serve as a practical complement to measures in the area of "Climate-Adapted Forest Management" ("Klimaangepasstes Waldmanagement") and the Joint Task "Improvement of Agricultural Structures and Coastal Protection."

The WKF funding guideline is currently undergoing an external evaluation. The funding guideline, which expires at the end of 2022, will be followed by a new guideline that takes account of the findings from that evaluation. Plans call for the WKF to place greater emphasis on funding of research, development and demonstration projects with stronger practical orientations. The WKF will then be charged with carrying out targeted, practice-oriented research and development projects that complement forest-based measures having effects over larger areas, such as those outlined in the framework plan for the Joint Task for the Improvement of Agricultural Structures and Coastal Protection (GAK), or in the "Action Programme for Natural Coastal Protection" ("Aktionsprogramm Natürlicher Klimaschutz – ANK).

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 adopted from the ERA-NET Sumforest policy, under which Germany is involved in six research projects within consortia.

In September 2021, against the background of the current ecological and economic challenges, the Working group on Forest and Wood Research" ("Arbeitsgruppe zur Wald- und Holzforschung" – AG WUHF), which had been established by the Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry of Education and Research (BMBF), with the participation of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), presented a report on research requirements and on the potential for structural improvements in German forestry and wood research. To make our forests fit for the future, we need to close relevant knowledge gaps; carry out capacity building; and – especially – interconnect all parts of the still-fragmented research landscape, and develop consistent digital measurement and modelling procedures covering all areas of the forestry and wood sector. In the framework of the Research for Sustainability (FONA) strategy, the BMBF has launched an initial funding activity, "Regional Innovation Groups for a Climate-Friendly Forestry and Wood Industry" ("Regionale Innovationsgruppen für eine klimaschützende Wald- und Holzwirtschaft" – REGULUS, to run 2022-2028), to address the recommendations of the Working group on Forest and Wood Research.

In the BMBF's "Sustainable Land Management" funding area, relevant findings and forward-looking concepts have been developed, since 2009, especially in regions of special relevance with regard to climate change, or in which especially large changes are taking place via land use and climate change. Integration of users and decision-makers within such research, and generation of implementation-oriented scientific findings, play an important role in the funding area.

This funding area is part of the BMBF's Research for Sustainability (FONA) strategy, which has the following strategic goals: 1. Achieving the climate goals, 2. Researching, protecting and utilising habitats and natural resources, 3. Developing our society and our economy – ensuring good living conditions throughout the country.

The BMBF funding measure "Innovation Groups for Sustainable Land Management" ("Innovationsgruppen für ein Nachhaltiges Landmanagement") was aimed at intensifying transfer of sustainability innovations into actual practice. 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, concentrated on implementing the energy transition at the regional level and on approaches and technologies for linking renewable energy and land use, with the minimum use of resources. For example, the innovation group APV-RESOLA – "Agrophotovoltaics: Contributions to Resource-Efficient Land Use" ("Agrophotovoltaik: Beitrag zur ressourceneffizienten Landnutzung") set up an agrophotovoltaic pilot system, in Heggelbach am Bodensee, and used it to study agro-PV technology scientifically and under real-world conditions, taking account of relevant economic, technical, societal and ecological aspects. The BMBF provided a total of 30 million EUR for the funding measure in the period 2014 – 2019.

The BMBF's "Innovative Communities" ("Kommunen innovativ") funding measure, by promoting cooperation between communities and science, industry and civil-society organisations, providing new impetus for the future of Germany's regions. It is working to enhance the quality of life, and to foster more-equal living conditions, throughout the entire country. The first two funding phases of "Innovative Communities," which ran from 2016 to 2020 (funding volume: 20 million EUR), were focussed on addressing demographic change and promoting sustainable use of land and area resources. In the measure, research teams bringing together community representatives and scientists developed innovations for urban development, infrastructure and public services. This led to practicable instruments for promoting demography-proof development, such as regional development concepts, new financing models and new forms of mobility. The 3th funding round of "Innovative Communities" (2021–2024; funding volume: 10 million EUR) is aimed at intensifying assistance for communities in economically underdeveloped regions. The goal is to develop sustainable public services that help lead to more-equal living conditions throughout the country. Along with improvements of public services, the programme is expected to consider the ecological aspects of sustainability – and help enhance energy efficiency and resource efficiency, promote circular economies, boost climate change mitigation and reduce land usage.

The BMBF funding measure "Resource-Efficient Urban Neighbourhoods" ("Ressourceneffiziente Stadtquartiere" – RES:Z) is promoting interdisciplinary and transdisciplinary projects that study, develop and test implementation-oriented concepts for water-resources management, land use and waste-stream management, in order to provide a basis for sustainable development of urban neighbourhoods. Aspects of energy efficiency and climate change adaptation play an important role in the projects. The BMBF is providing about 33 million EUR for the funding measure in the period 2017 – 2025. The BMBF funding measure "Urban-Rural" ("Stadt-Land-Plus") addresses the joint sustainable development of cities, peri-urban areas and rural areas, especially with regard to development of sustainable regional circular economies, and to improvement of the bases for making decisions on sustainable land management. The thematic clusters being studied include integrated urban development, regional products, regional material cycles and regional justice. The BMBF is providing about 50 million EUR for the funding measure in the period 2018 – 2025.

The BMBF funding measure “Regional Innovation Groups for a Climate-Friendly Forestry and Wood Industry” (“Regionale Innovationsgruppen für eine klimaschützende Wald- und Holzwirtschaft” – REGULUS (to run 2022-2028) is aimed at developing actionable solution concepts and strategies for a sustainable forestry and wood sector. Its central goals include safeguarding and increasing forests’ CO_2-sink function. As a result, REGULUS contributes to implementation of the guiding principle of climate-friendly forest management that addresses climate change, takes account of economic interests and protects natural systems. As of 2022, in all likelihood, its thematic areas will be studied in model-region formats, by interdisciplinary and transdisciplinary collaborative R&D networks. REGULUS is part of an integrative reorientation and reinforcement of forest and wood research in Germany, and a contribution to the milestones of the “Forest Strategy 2050” (“Waldstrategie 2050”).

8.2.2 Modelling and forecasting

Since climate modelling is still the only instrument available for attempts at forecasting the future climate, improvements in the validity and reliability of climate models are of central importance.

Climate forecasts are based on sophisticated numerical climate models that simulate – as accurately as possible – global atmospheric and oceanic circulations. For such models, the German High Performance Computing Centre for Climate- and Earth System Research (DKRZ) and the Supercomputing Centre (JSC) at the Jülich Research Centre (FZ Jülich) provide supercomputing resources to other German research institutions. In the first quarter of 2022, a new supercomputer was commissioned at the DKRZ that will be used for executing and improving sophisticated scenario calculations needed for future global and regional climate models. In addition to being able to carry out higher-resolution model calculations, the supercomputers at the DKRZ and the FZ Jülich can also execute calculation runs for improved Earth-system models that simulate the climate system’s physical processes more effectively than previous models have done. As a result, these resources will make it possible to further reduce the uncertainties regarding the future development of living conditions on the Earth.

At the DKRZ, and with the support of BMBF project funding, climate simulations were carried out in the framework of Coupled Model Intercomparison Project 6 (CMIP 6) – and, therefore, in preparation for the Sixth IPCC Assessment Report. Simulations with climate and Earth-system models make it possible to carry out studies on climate variability and for detection of the climate “signal” within the “noise” of climate variability. Such studies have focussed, and continue to focus, on the question of the presence of a human “fingerprint” in the climate data collected since the beginning of the Industrial Revolution. The available collected data (from data networks, measurement campaigns, paleoclimatology, remote sensing) are used for model validation. Conversely, the models are used for reconstruction and interpretation of current and past climate states. The European Centre for Medium-Range Weather Forecasts (ECMWF), of which Germany is a Member State, operates the world’s most-comprehensive data-assimilation system.

In addition, in the BMBF’s “WarmWorld” funding measure, a new climate model, with extremely high resolution, is being developed on the basis of the ICON (ICOsahedral Non-hydrostatic) model platform. It will provide an innovative reorientation of climate projections that will make it possible, for the first time, to simulate weather in a warming climate. In this effort, elimination of systematic errors in the model is significantly reducing the uncertainties in the climate projections. This measure is based on a previous BMBF funding priority,

"Cloud and Precipitation Processes in the Climate System" ("Wolken- und Niederschlagsprozesse im Klimasystem" ($HD(CP)^2$)). In that effort, cloud-formation processes, precipitation formation and precipitation processes were physically modelled in ICON, with varying degrees of resolution.

With the new global climate model, resolution at all relevant scale levels, from global to local, will be possible, meaning that it will be possible to carry out consistent global and regional climate simulations in one and the same model. In particular, the model will facilitate more-reliable conclusions regarding possible climate developments in specific regions – such as at the German Länder (state) level. This will improve strategies for addressing climate change, and for adaptation to the concomitant weather extremes. The sound scientific basis provided by the model will facilitate more-reliable measures for climate-change mitigation; for assessment of climate change impacts; and for emissions reduction and adaptation to impacts.

Various working groups based in Germany are contributing to the international Coordinated Downscaling Experiment (CORDEX) project by providing regional climate projections for Europe and for other regions.

The ROMIC project is studying the influence of solar variability on climate, as well as the complex coupling mechanisms in atmospheric layers, in light of anthropogenic changes.

The strategic aim of the PalMod measure is to assess future climate projections for this century, via simulation of the last glacial-interglacial cycle, and with complex Earth-system models. In this project, previously neglected processes – such as the carbon cycle, and dynamic developments of sea ice and ice sheets – are being implemented within the Earth-system model. The BMBF's "Medium-Term Climate Predictions" ("Mittelfristige Klimaprognosen" – MiKlip) funding priority is an operational climate-forecasting system decade-based climate predictions. It is now being operated by the DWD. The forecasting system takes account of both anthropogenic climate changes and natural climate variations, at regional and global scales. The climate forecasts that it makes possible, in combination with comprehensive assessments of the quality of such forecasts, also provide a basis for improving the ability of industry and society to adapt to future climate fluctuations.

CLOUD is yet another research measure that is illuminating the physical interrelationships between cloud formation and clouds' impacts on climate. The aim of the CLOUD project, which is sited at CERN (particle accelerator; European Organization for Nuclear Research), is to provide a sound, quantitative picture of the possible interrelationships between galactic cosmic radiation (GCR) and the Earth's climate. The CLOUD consortium is studying the GCR's influence on atmospheric chemistry, aerosol particles and clouds, with a view to illuminate the role of a possible indirect solar contribution to climate change.

8.2.3 Climate impacts research

Climate impacts research, which studies the interactions between climate changes, natural systems and human society (socioeconomic systems), provides the scientific foundations for concrete measures for adaptation to climate changes.

Via the BMBF funding measure "Urban Climate Under Change" ("Stadtklima im Wandel"), a scientifically sound, practicable range of instruments for tackling problems tied to current and future climate conditions was developed. The instruments include an urban-climate model that simulates atmospheric processes at the building level and places them in the

context of microclimatic interactions. This facilitates interdisciplinary analyses for assessment of urban climates, and it supports planning of measures for improving such climates.

The Potsdam Institute for Climate Impact Research (PIK) studies key questions pertaining to climate impacts. At the PIK, scientists and social scientists collaborate interdisciplinarily, with the aim of improving the scientific basis for relevant decisions in the areas of policy, the economy and civil society. The PIK maintains numerous national and international cooperation relationships.

Between 2012 and 2012, the BMBF funded the coordination office at the PIK for the Inter-Sectoral Impact Model Intercomparison Project (ISI-MIP). ISI-MIP was aimed at developing simplifications and standards (simulation protocols) that would make it possible to link different, largely separate areas of sectoral-impact research more effectively, and thereby to carry out intercomparisons of different assessments of climate impacts and their uncertainties. The ISI-MIP modelling runs provided important contributions for the IPCC's Assessment Reports and special reports.

AXIS (Assessment of Cross(X)-sectoral climate Impacts and pathways for Sustainable transformation), a European research programme that is being funded by the BMBF and 10 additional European funders, carries out cross-sectoral, integrated assessment of selected climate-impact phenomena (time period: 2019–2023).

The Institute for Advanced Sustainability Studies (IASS – Institut für transformative Nachhaltigkeitsforschung), which is funded by the BMBF and the state of Brandenburg, carries out holistic, interdisciplinary, transdisciplinary and international research on, inter alia, climate change, components of the Earth system and sustainability. In the process, it focuses on societal processes of change and transformation. Against this background, and in developing adaptation and reduction strategies, it takes account of findings from science, the social sciences and the humanities. As a mediator between the areas of science, civil society, industry and policy, the institute makes important contributions to transfer of results into practical applications.

In the BMEL-commissioned project "Climate-change-related harvest changes and land use" ("Klimawandelbedingte Ertragsveränderungen und Flächennutzung"), which was completed in spring 2022, a collaborative project network comprising Deutscher Wetterdienst, Julius Kühn Institute, Leibniz Centre for Agricultural Landscape Research and Thünen Institute prepared a comprehensive overview of current knowledge about how climate impacts could affect German crop cultivation. The project provided model-based, quantitative and spatially differentiated simulations showing how harvests of the most important German crops could change by the middle of the century.

8.2.3.1 Funding of research and development on climate-change impacts and on adaptation

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" ("Forschung für Nachhaltigkeit") (FONA strategy). Other ministries also have programmes that are testing adaptation measures on a pilot basis. Examples include the "Adaptation to the Impacts of Climate Change" ("Anpassung an die Auswirkungen des Klimawandels") programme of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), and the ImmoKlima and StadtKlima research fields within the Experimental housing and urban development programme (ExWoSt) of the Federal Ministry for

Housing, Urban Development and Building (BMWSB). In the framework of the Network of Experts founded in 2016 by the Federal Ministry for Digital and Transport (BMDV), the ministry (BMDV) is financing research activities that address the need to adapt transport infrastructure and transport systems to climate change. The activities are practically oriented, and they apply a cross-cutting perspective to government agencies and modes of transport. The research findings enter into the “Climate and Water” basic service of the German Strategy for Adaptation to Climate Change (DAS). “Climate and Water” is a BMDV-commissioned operational climate service that provides advising and data relative to climate and water issues, in the context of adaptation to climate change.

In addition, contracts for fixed-term research and development projects are awarded, via competitive procedures in the framework of funding and specialised programmes. For example, the BMBF has funded major collaborative research projects in this area, aimed at regions or cities.

The federal government's activities in this area are combined and coordinated by the Interministerial Working Group on Adaptation to Climate Change (IMAA). Such coordination leads into the German Strategy for Adaptation to Climate Change (DAS) and its regular updates, which are supplemented by action plans (cf. Chapter 7). A new climate-adaptation strategy, with measurable goals, is currently being prepared in the IMAA framework.

8.2.3.2 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. 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. In connection with the progress report for DAS (2015), it was agreed that a vulnerability analysis would be carried out every 6 years, and that the findings, data and methods used for the vulnerability analysis would be regularly reviewed. The latest such analysis, the “Climate Impacts and Risk Analysis for Germany” (“Klimawirkungs- und Risikoanalyse für Deutschland”) dates from June 2021.

8.2.4 Socio-economic research into the causes and consequences of climate change

8.2.4.1 Socio-ecological research

The priority aim of the funding priority “Socio-ecological research” is to develop, in cooperation with stakeholders, strategies and options for implementing the German Sustainable Development Strategy. It addresses problems that occur in interrelationships between people and their natural and societal environments. The options for shaping such interrelationships

are being studied from a cross-discipline perspective. In the process, special attention is being given to ensuring that findings regarding the social dimension of sustainability are accorded the same importance that scientific findings receive.

Climate-relevant projects in socio-ecological research are being carried out in:

- Projects within the funding priority “Sustainable Development of Urban Regions” (“Nachhaltige Stadtentwicklung”),
- Projects within the initiative “Sustainability in Science” (SiSi),
- Projects being carried out by junior research groups working in the area of socio-ecological research.

In the funding priority “Sustainable Development of Urban Regions,” and within the measure “Sustainable Transformation of Urban Areas” (“Nachhaltige Transformation urbaner Räume”), the BMBF is funding eleven projects (with a funding volume of about 11 million EUR) with research focuses oriented explicitly to energy policy and climate policy, such as low-carbon housing, near-home mobility access, and public participation in climate-friendly urban redevelopment. This funding priority also includes the BMBF research agenda “Sustainable Urban Mobility” (see below, Chapter 0 Climate protection and mobility).

In the initiative “Sustainability in Science” (SISI), the BMBF has been funding climate-relevant projects since 2013. One example is the funding measure “Transformation Pathways for Sustainable Universities” (“Transformationspfade für nachhaltige Hochschulen”), in which eleven projects (funding volume of about 15 million EUR) are studying ways of making universities, in their totality as institutions, climate-neutral and energy-efficient. This includes strategies such as alternative financing and operational models for ecological building refurbishments, real-world laboratories for development of bicycle-based mobility concepts, and integration of climate-relevant advising services within universities’ operations and teaching.

Also within the framework of socio-ecological research, funding totalling about 30 million EUR is being provided for a total of 14 junior research groups conducting research with a direct orientation to energy / climate issues. These groups are focussing on the interrelationships between environmental change – especially climate change – and migration, climate finance, energy system transformation and biodiversity / land use.

8.2.4.2 Economic aspects of climate change

As climate change accelerates, the debate about its economic dimensions is intensifying. Efforts to achieve climate goals are closely linked to economic issues and challenges.

In the “Economics of Climate Change” funding priority, therefore, the BMBF is funding 29 R&D projects and a supporting process, “Dialogue on Climate Economics” (“Dialog zur Klimaökonomie”), with a budget of 24.7 million (the projects run from the end of 2018 to the end of 2022). The projects address key tasks and issues of climate policy. The measure has five overarching thematic priorities:

- Climate change mitigation and transformation: decarbonisation, competitiveness, quality of life
- Climate change mitigation: Instruments and policies after COP21
- Dealing with climate hazards
- International climate policy

- Financial markets, finance industry and financing.

A supporting process, “Dialogue on Climate Economics,” promotes exchanges between researchers, policymakers and other stakeholders (from areas such as industry and civil society) and provides an attractive platform for communication and interaction.

In ongoing projects, the German Environment Agency (UBA) carries out in-depth economic analysis of individual policy instruments and measures for adaptation to climate change. On the one hand, such analysis seeks to financially quantify – where possible – the potential damages caused by climate change. On the other, it strives to economically justify optimal combinations of policies and adaptation measures.

Key roles in decarbonisation are played by a) financing for the concomitant economic transformation, and b) efforts to develop a sustainable finance system. In keeping with these roles, in 2022, and in the framework of the federal government's Sustainable Finance Strategy, the BMBF funding measure “Climate Protection & Finance Industry” (“Klimaschutz & Finanzwirtschaft” – KlimFi)“ (funding budget: 11 million euro). The measure seeks to promote intensive exchanges between the science, finance industry, real economy, policy-making and societal sectors. The research projects will yield new knowledge and recommendations concerning the following: how the finance industry and financial markets can contribute to climate action; how relevant financial products, market mechanisms and framework conditions in financial markets should be designed; and how the finance industry can best respond to the profound changes occurring in the real economy and society, with respect to climate action.

8.2.5 Research and development on mitigation and adaptation measures, including relevant technologies

8.2.5.1 Applied adaptation research

Under the umbrella of the FONA strategy, the federal government funds applied adaptation research, and scientific studies on adaptation to climate change, and presents resulting research findings. Such results enter into expert-level exchanges carried out with various departments (such as the Interministerial Working Group on Adaptation to Climate Change (IMAA)), and between federal authorities and various experts – for example, experts at Land (state) agencies and in the science sector. The federal government's research activities are summarised in the Action Plan for Adaptation (Aktionsplan Anpassung), which was last updated in 2020, to a third version (cf. Chapter 7).

Via transdisciplinary and needs-oriented research, in its funding measure “Climate resilience via action in cities and regions” (“Klimaresilienz durch Handeln in Stadt und Region”), the BMBF is helping to address regional challenges of climate change. On the basis of specific climate-adaptation needs, projects are developing and testing innovative measures and options in cooperation with local stakeholders. The efforts are expected to yield multiple benefits, by strengthening stakeholders’ adaptation capacities and also making contributions to climate action and/or other areas of sustainable development activity. In addition, improvements in methods for determining adaptation capacities and adaptation progress are expected.

At the same time, expertise in the area of the social sciences and humanities has also been included: The BMBF’s interdisciplinary funding measure “Social Dimensions of Climate Action and Climate Change” (“Soziale Dimensionen von Klimaschutz und Klimawandel”) has helped to reinforce social-science and humanities expertise in the area of climate research,

by raising awareness about social factors and impacts in climate change, and by supporting the design of policies in connection with climate action and climate change mitigation.

The BMBF funding measure “Regional Information for Action on Climate Change” (“Regionale Informationen zum Klimahandeln” – RegIKlim) is supporting cities and regions in actively and efficiently addressing climate change and its concomitant environmental stresses. The measure is aimed at helping local stakeholders acquire the knowledge they need in order to be able to carry out their own forward-looking adaptation measures. In six model regions, and in the framework of transdisciplinary projects, new tools for addressing the problems are being developed locally, in cooperation with stakeholders from the areas of policy, administration and business. On the basis of specific climate-change signals, and in keeping with spatial and landscape circumstances, information tools for supporting decisions on regional adaptation to climate change are being developed. In addition, research is addressing fundamental aspects for the regions, with regard to climate change adaptation. The focus in this regard is on the thematic areas of a) adaptation capacities and b) integrated assessment of climate hazards and options for action. In two cross-cutting projects, a regional climate cadastre is being developed that will provide regional and local climate information for the model regions and other regions.

The BMBF initiated the immediate-action measure “Scientific support for the rebuilding process following the disastrous floods in Rhineland-Palatinate and North Rhine-Westphalia – Climate adaptation, floods and resilience” (“Wissenschaftliche Begleitung der Wiederaufbauprozesse nach der Flutkatastrophe in Rheinland-Pfalz und Nordrhein-Westfalen – Klimaanpassung, Hochwasser und Resilienz” – KAHR) in response to the disastrous floods in Rhineland-Palatinate and North Rhine-Westphalia in July 2021. The measure is aimed at supporting the affected regions in both German Länder with scientific expertise as they rebuild. In this connection, it is supporting the rebuilding process by providing local stakeholders and actors with the latest scientific findings on climate change and on climate change adaptation.

It is becoming increasingly important for infrastructure to be designed in climate-robust ways – especially because of infrastructure’s susceptibility to extreme climate events; its key supply role in the economy and society; its long service life; and the fact that its construction requires long planning periods. In a number of projects, the German Environment Agency (UBA) is examining the vulnerability of infrastructure to climate change and developing approaches to designing climate-resilient infrastructure. The projects are working to highlight the ways in which modern infrastructures are interlinked; what vulnerabilities they have; and what characteristics future infrastructures will need to have in order to be climate-resilient and sustainable. The effort also includes consideration of social, organisational and institutional issues related to the adaptation of existing infrastructures and to alternative infrastructures.

In two projects, and applying a cross-cutting perspective, the UBA is studying 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 a climate-resilient society might look like. Another UBA project is evaluating 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. The results of the effort are being summarised in a practical guide. Two other UBA projects are also focussing on supporting practitioners: A project on “Good practice in climate change adaptation in Germany” (“Gute Praxis der Anpassung an den Klimawandel in Deutschland”) is compiling knowledge on adaptation for stakeholders at the regional and local-authority levels and is identifying examples of good

practice with the aim of supporting adaptation in business and individual behaviour. A project on “Empowering local authorities” (“Kommunen befähigen”) is exploring the factors and conditions that decisively influence municipalities’ adaptation capacities in Germany. Against this backdrop, the project is developing 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 information, tailored to the target groups in question, to assist people in taking their own precautionary measures.

The national impacts of climate change make up another relevant thematic area. In this area, the German Environment Agency is conducting projects on foreign trade and migration.

The adaptation process in Germany has been, and still is, shaped by a series of participatory procedures relative to implementation of the German Strategy for Adaptation to Climate Change and the Adaptation Action Plan. Other UBA projects are evaluating existing cooperation and participatory procedures in Germany, and testing innovative participation formats. Their purpose is to help improve and consolidate climate change adaptation activities that have already been launched at the federal, Land and municipal levels.

Agriculture

In addition to breeding efficient crop varieties that are adapted to changing climatic conditions, i.e., are resistant to or tolerant of abiotic and biotic stress, the Julius Kühn Institute (JKI) also develops crop cultivation strategies to reduce climate-related risks. In addition, it devises crop-protection concepts and strategies calling for prompt use of appropriate methods to counter climate-related changes or shifts in the pathogen and pest spectrum. Robust plant growth models for various relevant crop species are produced on the basis of JKI’s own long-term field trials, and supplemented by long-term field-trial data from institutions run by the Länder at multiple locations (including trials of cultivars specific to individual Länder). The models enable JKI to analyse climate-induced changes over time and to develop climate-adaptation strategies, for crop husbandry, that make agronomic, economic and environmental sense.

In this specialised context, the BMBF, working under the umbrella of the National Bioeconomy Strategy (previously known as the National Research Strategy Bioeconomy 2030), administrates an extensive portfolio of funding measures focussed on the concrete contributions that a bioeconomy makes to climate and environmental protection. By way of example: Since 2016, the BMBF has been funding – with funding of some 56 million euro – the measure “Plant Breeding Research for Bioeconomy” (“Pflanzenzüchtungsforschung für die Bioökonomie”). The relevant funding guideline is focussed – taking special account of issues pertaining to biodiversity, environmental protection and climate protection – on both a) the creation of a plant-based foundation for sustainable food production and b) provision of high-quality products made from renewable raw materials. The purpose of the multi-phase funding (3 x 3 years) is to significantly increase knowledge production that can serve as a basis for new innovations in plant-breeding research. Also, in 2020, the BMBF published the funding announcement “Epigenetics – Chances for Plant Research.” With this measure, the BMBF is funding projects that help to generate a detailed understanding of epigenetic processes in plants. The funding guideline’s primary aim is to improve our understanding of the biological foundations of epigenetics. In the long-term, the resulting findings will serve as a basis for breeding climate-adapted crops.

Forests and Forestry

The Forest Climate Fund (Waldklimafonds), which is jointly managed by the Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), supports several research and development projects on strategies for adapting forests, and sustainable management of forests, to climate change.

The Thünen Institute is developing the scientific basis for site-appropriate forest conversions, and it carries out economic assessments that provide a basis for decisions on adaptation measures. By facilitating prompt, effective precautionary measures, development and establishment of monitoring systems help to counter the introduction and spread of new pests. A special emphasis of efforts in this area is on protecting forests' genetic resources, as a key to strengthening forests' adaptation capacities.

In September 2021, against the background of the current ecological and economic challenges, the Working group on Forest and Wood Research" ("Arbeitsgruppe zur Wald- und Holzforschung" – AG WUHF), which had been established by the Federal Ministry of Food and Agriculture (BMEL) and the Federal Ministry of Education and Research (BMBF), with the participation of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), presented a report on research requirements and on the potential for structural improvements in German forestry and wood research. To make our forests fit for the future, we need to close relevant knowledge gaps; carry out capacity building; and – especially – interconnect all parts of the still-fragmented research landscape, and develop consistent digital measurement and modelling procedures covering all areas of the forestry and wood sector. In the framework of the Research for Sustainability (FONA) strategy, the BMBF has launched an initial funding activity to address the recommendations of the Working group on Forest and Wood Research.

The BMBF funding measure "Regional Innovation Groups for a Climate-Friendly Forestry and Wood Industry" ("Regionale Innovationsgruppen für eine klimaschützende Wald- und Holzwirtschaft" – REGULUS, to run 2022-2028) is aimed at developing actionable solution concepts and strategies for a sustainable forestry and wood sector. Its central goals include safeguarding and increasing forests' CO_2-sink function. As a result, REGULUS contributes to implementation of the guiding principle of climate-friendly forest management that addresses climate change, takes account of economic interests and protects natural systems. Its thematic areas are being studied in model-region formats, by interdisciplinary and transdisciplinary collaborative R&D networks. Consequently, REGULUS is part of an integrative reorientation and reinforcement of forest and wood research in Germany, and a contribution to the milestones of the "Forest Strategy 2050" ("Waldstrategie 2050").

8.2.5.2 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.

In 2019, in an effort to address the rapid, ongoing losses of biodiversity, the BMBF initiated the "Research Initiative for the Conservation of Biodiversity" ("Forschungsinitiative zum Erhalt der Artenvielfalt" – FEdA). It is aimed at strengthening research in this area, with a view to closing gaps in knowledge about systemic connections of relevance to biodiversity loss, and to developing effective strategies for addressing this issue. The research initiative is seeking to develop action strategies – and utilisation concepts with lasting viability – that can protect ecosystem services. For example, the funding measure "Valuation and

Preservation of Biodiversity in Policy, Economy and Society" ("Wertschätzung und Sicherung von Biodiversität in Politik, Wirtschaft und Gesellschaft" – BiodiWert) has been underway in the FEdA framework since 2020. Currently, this effort is funding a total of 17 projects that, by developing innovative valuation concepts, governance structures and (policy) measures, are increasing the value of ecosystem services and biodiversity as perceived on entrepreneurial and societal levels – and are thereby, by helping to protect biodiversity, ultimately helping to protect the climate.

The BMBF has supported BiodivERsA, a European research funding network, since 2005. This provides a means of contributing national research expertise to collaborative research projects in Europe and worldwide. Since 1 October 2021, the network is being managed in the framework of Horizon Europe as the Biodiversa+ European biodiversity partnership. Its current focuses include the impacts of climate change on biodiversity; options for restoring ecosystems; and strategies for supporting biodiversity and ecosystems on land and in the sea. The German research fleet researches biodiversity and changes to biodiversity in the oceans around the world.

Germany's institutional support for climate-oriented ecosystem and biodiversity research extends to centers of the Helmholtz Association of German Research Centres (HGF), of the Max Planck Society (MPG), of Fraunhofer-Gesellschaft (FhG) and of the Leibniz Association (WGL). In the Helmholtz Association, such research is carried out in the research area "Earth and Environment," in the programmes "Geosystem: The Changing Earth," "Marine, Coastal and Polar Systems," and "Terrestrial Environment"; in the Leibniz Association, it is carried out primarily in the sections "E – Environmental Research," "C – Life Sciences," and "B – Economics, Social Sciences, Spatial Research" and, cross-sectionally, in the Leibniz research networks "Biodiversity," "Environmental Crisis – Crisis Environments," "Integrated Earth System Research" and "Mathematical Modelling and Simulation (MMS)."

In 2016, the Alfred Wegener Institute for Polar and Marine Research (AWI) and the University of Oldenburg joined forces to set up the Helmholtz Institute for Functional Marine Biodiversity. The Helmholtz Institute is located on the campus of the Carl von Ossietzky University of Oldenburg.

Other important institutions in Germany that work on the interactions between climate change and ecosystems include:

- Helmholtz Centre for Environmental Research (UFZ), Leipzig
- Bayreuth Center of Ecology and Environmental Research (BayCEER)
- Senckenberg Biodiversity and Climate Research Centre (BIK-F), Frankfurt
- German Centre for Integrative Biodiversity Research (iDiv), a consortium of eleven research institutions with main locations in Halle, Jena and Leipzig
- 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 (JKI), especially in the following JKI institutes: Bee Protection (since 2016), Strategies and Technology Assessment, and Biological Control

8.2.5.3 Coastal regions

The BMBF funds interdisciplinary and transdisciplinary research in support of conservation of coastal ecosystems and their ecosystem services; integrated coastal protection; and the sustainable management of coastal zones. In such research, 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 models for forecasting climate-change impacts and changes in conditions of use.

Since 2012, the "Coastal Research North Sea / Baltic Sea" ("Küstenmeerforschung in Nord- und Ostsee - KüNO"[201] programme has been working to establish a scientific basis for ecosystem-oriented management of coastal resources. Currently, 7 collaborative research networks are being funded in this funding priority. Their research focuses include the following:

- Protecting the ecosystem services provided by German coastal systems, in the face of changes in use and climate change,
- Improving forecasting and assessment of the impacts of global change on coastal ecosystems,
- Research to facilitate evidence-based implementation of integrated marine policy at the national and EU levels,
- Identification of climate-related security risks; further development of design procedures and infrastructures in coastal protection; and development of appropriate planning and decision-making tools, with the aim of achieving sustainable coastal management.

In addition, and in the framework of the research mission "Protection and Sustainable Use of Marine Areas" (Schutz und nachhaltige Nutzung mariner Räume"[202]), efforts are underway to improve our understanding of the ecological risks occurring as a result of sea-level rises, warming, pollution and overuse, and of the associated cascading and mutually reinforcing effects. Five interdisciplinary and transdisciplinary collaborative research networks, working under the umbrella of the German Marine Research Alliance (DAM), and in cooperation with various user groups, are developing strategies for protecting German coastal waters and for sustainably using marine resources. This work includes studies on ways of avoiding use of mobile bottom-contacting fishing gear (MBCF; bottom trawling) in the North Sea and Baltic Sea.

- Climate- and weather-related natural hazards require the Länder along the north German coast to invest extra effort in coastal protection, and the BMBF has been constantly involved in the German Coastal Engineering Research Council (KFKI) for several decades. In this research programme, the 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.

With its activities relative to coastal sea research, Germany supports international research programmes: The World Climate Research Programme (WCRP); Land-Ocean Interactions in Coastal Zones (LOICZ), within the International Geosphere-Biosphere Programme

[201] https://deutsche-kuestenforschung.de
[202] https://www.allianz-meeresforschung.de/kernbereiche/forschung/meere-schuetzen-und-nachhaltig-nutzen/

(IGBP); and the UN marine conservation programmes (including the 2030, SDG14 and the UN Ocean Decade).

8.2.5.4 Key technologies, and cross-cutting technologies, for climate change mitigation

Research and development in key technologies make it possible to improve climate protection in many different applications. Ambitious climate goals will be achieved only with the help of research and development in key technologies and cross-cutting technologies. Such technologies have effects in all sectors of relevance for climate protection. For this reason, the Federal Ministry of Education and Research (BMBF) provides extensive support for key technologies and cross-cutting technologies in numerous thematic areas:

- One important pillar of such support, for example, is a major research initiative on "green hydrogen" that is being carried out in the framework of the National Hydrogen Strategy. Also, information and communications technologies (ICT) and new materials enhance productivity in renewable energies, a central area.
- A second central research area has to do with decarbonisation of important industrial sectors, via reductions of process-related emissions in basic materials industries (for example, via the BMBF's "KlimPro Industrie" measure); use of CO_2 as a raw material in industry; and innovations for climate efficiency (via the BMBF's "SME Innovative: Resource Efficiency and Climate Protection" ("KMU-innovativ Ressourceneffizienz und Klimaschutz") measure).
- On a cross-cutting basis, ICT helps reduce carbon footprints. For example, ICT improves the control – and, thus, the energy efficiency – of production and energy systems.
- In the forestry and agricultural sectors as well, key technologies and cross-cutting technologies facilitate climate-neutral operations and production chains, and help tap potential for increasing sink functions.
- In the mobility sector, battery research plays a central role. Also, new high-tech materials are making vehicles lighter, and batteries stronger. Overall, innovative system solutions are helping to change emissions trends in this sector.

8.2.5.5 Research for renewable energies

The energy system transformation is an enormous transformation project. It is thus not surprising that the number of research projects, and the funding budget for energy research, have both grown. In the framework of its 7th Energy Research Programme, the federal government invested 1.311 billion euro in energy research in 2021. That level of federal funding represents an 8 percent increase over the previous year's funding level, 1.216 billion euro.

Thema	Mittelabfluss in Mio. €							
	2014	2015	2016	2017	2018	2019	2020	2021
Projektförderung	487,65	525,44	536,28	659,45	635,25	703,66	750,59	945,17
Strategische Förderformate						–	5,53	66,93
Energiewende in den Verbrauchssektoren	115,89	112,04	108,08	137,28	156,04	193,92	208,03	212,92
Energieerzeugung	198,95	209,86	191,67	244,49	212,36	255,36	252,60	288,39
Systemintegration: Netze, Speicher, Sektorkopplung	95,22	113,30	119,79	144,44	127,15	127,11	146,61	201,69
Systemübergreifende Forschungsthemen der Energiewende	34,29	44,49	71,01	86,12	92,22	78,31	91,61	123,42
Nukleare Sicherheits-forschung	43,29	45,74	45,73	47,13	47,48	48,98	46,21	51,82
Institutionelle Förderung (HGF)	331,60	348,69	362,81	379,63	393,75	410,29	415,78	314,42
Begleitende Maßnahmen	28,14	34,72	35,03	28,20	25,76	34,47	49,63	51,38
Gesamt	847,39	908,85	934,12	1.067,28	1.054,75	1.148,42	1.216,00	1.310,97

Table 16: Overview of thematic areas in the federal government's 7th Energy Research Programme; Source: 2022 Federal report on energy research (Bundesbericht Energieforschung 2022)[203]

With funding of 878.24 million euro, the programme is supporting research, development and demonstration projects of strategic importance for the long-term success of Germany's Energiewende energy system transformation. In 2021, the federal government funded a total of 6,995 ongoing research projects (2020: 5,980 projects). 2,016 projects were approved for the first time (2020: 1,590 projects). An additional 314.42 million euro were invested in institutional support for the Energy research area of the Helmholtz Association of German Research Centres.

The 7th Energy Research Programme covers the entire innovation cycle – from basic research to testing of new or improved technologies shortly before their market launch.

In photovoltaics research, efforts are currently being consolidated, with a view to moving production technologies into the terawatt market. Along with strategies for increasing throughput, this especially entails development of material-efficient and resource-saving technologies. Integrated photovoltaics (building-integrated PV; vehicle-integrated PV; Agri-PV) is also growing in importance.

In wind energy research, the predominating aspects include: achieving further reliability increases for wind farms; developing cost-saving, material-efficient operational and maintenance concepts; and developing accelerated system and component tests. Research wind farms have been developed for study of how wind turbines influence each other in wind farms, and of various aspects of wind energy use in complex terrains.

The research area for energy-related use of biogenic residual and waste substances is focussed on finding ways to use biomass types that have not been used to date. Also, it is exploring the use of storage-capable biomass, as a flexibilization option for a future energy system based on fluctuating feed-in of renewable energy sources.

Via its "Renewable Resources" funding programme, the BMEL is also supporting research and development in the area of bioenergy. The projects are managed by FNR (Fachagentur

[203] German Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz 2022): Bundesbericht Energieforschung. URL: https://www.bmuv.de/download/bundesbericht-energieforschung-2022

Nachwachsende Rohstoffe e.V. – Agency for Renewable Resources), acting as BMEL's project administration agency. Since 2015, research funding in the bioenergy sector has focussed on the following priorities:

- Developing technologies and systems for producing and utilising bioenergy with the objective of further reducing GHG emissions;
- Developing flexible, efficient bioenergy systems for generation of renewable energies (electricity, heat, and power for mobility), with such development occurring in connection with systems integration and sector coupling.

A total of 154 projects were funded in the area of energy-related uses / bioenergy fuels. The funding provided amounted to about 41 million EUR (as of October 2022).

The largest share of the projects consists of projects for improving the carbon footprints of bioenergy applications. The range of projects includes projects for biomass production; conversion processes; and biomass utilisation in the electricity, heating/cooling and transport sectors. In addition to emissions avoidance, the focuses include improving energy efficiency and making use of residual and waste substances.

The second funding priority concerns research into the possibilities of bioenergy as an element in systems dominated by renewable energy sources. The main emphases in this area include 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 being funded under the Renewable Resources funding programme. Issues surrounding energy recovery from biogenic residues and wastes; renewable heating energy; and energy from aquatic systems play an important role in this area.

Since 2020, and in the framework of "Renewable Resources" funding programme, projects on energy recovery from farm manure are being supported, in a complementary role, with funding from the Climate and Transformation Fund (KTF/EKF). Since early 2022, and in the framework of the BMEL's "Guideline on funding of investments in emissions-reduction measures in connection with digestion of farm manure" ("Richtlinie zur Förderung von Investitionen in emissionsmindernde Maßnahmen bei der Vergärung von Wirtschaftsdünger"), investment projects may also be funded, along with a) research and development projects and b) model and demonstration projects.

To be effective with regard to climate protection, new technologies need to be able to move rapidly out of laboratories and into industry and society. For this reason, in its 7th Energy Research Programme, the federal government has placed special emphasis on accelerated transfer of innovations into the energy industry sector, and into society, and it has created new strategic funding formats for supporting such transfer. Funding of research into hydrogen technologies, in particular, has increased considerably, in connection with the federal government's National Hydrogen Strategy (NHS).

The NHS provides a coherent framework for the future generation, transport and utilisation of hydrogen, and it lays a foundation for the market launch of new technologies and systems. In 2021, the BMBF and the BMWK initiated large-scale research initiatives that are making significant progress toward goals in this area. In spring 2021, the BMBF's industry-led lead projects on hydrogen were launched. In these efforts, more than 200 partners from science and industry are conducting research in three central fields of innovation: H2Giga is focussing on series production and scaling of electrolysers. H2Mare is studying offshore hydrogen production, and TransHyDE is working on hydrogen-transport solutions. Initial

projects for basic research into green hydrogen have also begun. These projects are researching key technologies for tomorrow and well into the future, throughout the entire hydrogen value chain.

Via international research partnerships – for example, with Canada, Australia and countries in Southern and West Africa – the BMBF is supporting the international development of the hydrogen sector. Initial results from the H2Atlas study have highlighted the great potential that the sub-Saharan region has for production and export of green hydrogen. The BMBF has established an "International Master's Degree Programm in Energy and Green Hydrogen" (IMP-EGH) for the purpose of building local expertise and training specialists. Along with application-oriented research, the focuses in connection with hydrogen technologies include a great many future-proof jobs, new value chains and a global market with revenues in the billions. The campaign is being supported by systems analysis oriented to a global hydrogen economy.

During the German EU Council Presidency, the BMBF initiated a Member-State-driven agenda process on research and innovation for green hydrogen, and then confirmed the process in connection with the set of conclusions the Council adopted regarding the new European Research Area (ERA). In 2021, pressing research and innovation issues were identified via a public, Europe-wide dialogue process. The results were consolidated within a Strategic Research and Innovation Agenda (SRIA) for the European Research Area and then published in 2022. A framework funding announcement published in March 2021 is promoting networking, between German stakeholders and international partners, throughout the entire hydrogen value chain. It serves as a basis for the design of precisely tailored funding concepts relative to green hydrogen.

The BMWK's real-world laboratories for the Energiewende energy system transformation are facilitating systemic testing of innovations and research findings in real-world settings and on an industrial scale. They are designed to accelerate technology and innovation transfer by closing the gap between research and actual operations in the energy industry. In short, they make it possible to carry out "dress rehearsals" prior to market launches. As a result, the real-world laboratories are contributing to the success of the Energiewende, by paving the way for new technologies and new value chains. To date, a total of ten real-world laboratories have begun their operations.

Real-world laboratories for the Energiewende, in the area "sector coupling and hydrogen technologies":

- H_2-Wyhlen
- Norddeutsches Reallabor
- Energiepark Bad Lauchstädt
- H_2Stahl
- WESTKÜSTE100

Real-world laboratories for the Energiewende, in the area "energy-optimised districts" ("Energieoptimierte Quartiere"):

- Large heat pumps in district-heating networks (GWP)
- Darmstädter Energie-Labor für Technologien in der Anwendung (DELTA)
- Integrierte WärmeWende Wilhelmsburg IW3

- TransUrban.NRW
- SmartQuart – Smarte Energiequartiere

The Trans4Real project has won the competition, among the real-world laboratories for hydrogen, of ideas for scientific transfer research. The real-world laboratories for energy-optimised districts are being supported by research in the area of “Building the Energiewende energy system transformation” (“Energiewendebauen”).

The systems-oriented energy research of the past few years has also focussed on instruments and measures relative to the Energiewende in consumption sectors; on aspects of energy generation and systems integration; and on inter-systemic research topics relating to the Energiewende and nuclear-safety research.

As important as support for market launch and mature-technology application is, basic research is just as important. The BMBF’s funding is consistently aimed at connecting basic research with industry requirements, in order to speed up the process leading from research ideas to market-ready innovations. Examples of this approach include the Copernicus projects for the Energiewende, and the Carbon2Chem research cluster. The Copernicus projects, whose second phase is being funded in the framework of the Climate Action Programme 2030, apply a systemic approach and have a ten-year time frame. Via the course of three funding phases, innovations in key areas of the Energiewende energy system transformation are being prepared via a process leading from a) theory and concept development to b) validation and c) large-scale demonstration.

The Energiewende calls for introducing renewables-based energy sources / fuels in all sectors of the energy system. To date, making the industry, transport and heat sectors climate-neutral has been an insurmountable challenge, however. Sector coupling is a strategy for decarbonising these sectors. Green hydrogen – produced from renewables-based electricity, via electrolysis – is seen as a key element in this regard. It can be used as a raw material in steel production or in the chemical industry, for example. In the transport sector, it can defossilise air transports and heavy traffic. It can be used either directly, in vehicles with fuel-cell drive, or indirectly, as a component of synthetic fuels for ships and aircraft. In this area, the BMBF is funding application-oriented basic research in the framework of the Federal Climate Action Programme 2030.

If the Energiewende is to be a success, existing technologies will also have to be improved and made more efficient. This will call for innovative materials, for example. For this reason, the BMBF has established a funding priority in the area of basic research for development of innovative materials. In 2021, projects underway in the area of materials research covered a wide range, including areas such as development of new materials for optimisation of PEM fuel cells; electrochemical energy-storage systems and wind turbines; promising high-performance materials for photovoltaics; and new materials for gas turbines.

The Academies Programme “Energy Systems of the Future” (“Energiesysteme der Zukunft”) combines the expertise available at the country’s academies of science. A BMBF-funded initiative being carried out by acatech, Leopoldina and Akademienunion is provided impetus for the ongoing debate about the challenges and chances Germany’s energy system transformation presents. In the ESYS project, more than 120 experts are developing options for implementing a safe and reliable, affordable and sustainable energy system. In 2021, for example, it developed proposals and position statements relative to climate-friendly expansion of photovoltaic and wind energy systems, and to the resilience of digitalised energy systems, and made them available for discussion.

8.2.5.6 Emissions reductions in industrial processes and products – Increasing resource efficiency and utilisation of CO_2

By decoupling economic growth from resources consumption, circular economies play a central role in sustainable development, and in efforts to achieve climate targets. In addition, lengthening products' useful lifetimes, and recycling of the materials they contain, enhances the security of supply and promotes independence from global resources markets. The BMBF's research concept "Resource-Efficient Circular Economy" ("Ressourceneffiziente Kreislaufwirtschaft"), which is being carried out in the framework of its Research for Sustainable Development (FONA) strategy, provides specifically targeted funding in this area. In the period 2018-2023, it is providing about 150 million EUR for relevant funding measures. Its central aim is to keep products, and the resources they contain, within circular economies as long as possible – and thereby to contribute to the planned National Circular Economy Strategy (Nationale Kreislaufwirtschaftsstrategie). This is to be achieved via innovative business models, in conjunction with digital technologies and sustainable product designs. The current funding measures in this area are briefly described in the following section.

The funding measure "Resource-efficient circular economy – Building and mineral cycles (ReMin)" is aimed at optimising mineral-substance cycles. It is focussed especially on the construction sector, with its great demand for raw materials, and on expanded use of secondary raw materials obtained from building rubble, slags, ash and mining residues. The project seeks to develop innovative processes that can return the valuable secondary raw materials found in mineral residual and waste substances back to material cycles. (key data for ReMin: 16 collaborative research projects, 1 networking and transfer project, funding of 22 million EUR, industrial contribution of 7 million EUR, to run from 2021 to 2024)

The funding measure "Resource-efficient Circular Economy – Plastic-recycling Technologies" ("Ressourceneffiziente Kreislaufwirtschaft – Kunststoffrecyclingtechnologien" – KuRT) is aimed at achieving considerable increases in actual recycling and recyclate-input rates for plastics. By promoting smart utilisation concepts for plastics, improved logistics and collection, and efficient use of plastic recyclates, the measure is expected to enhance the cost-effectiveness of circular economies for plastics, and the quality of plastic recycling. The funding measure, which has two phases, will aim to improve exemplary circular-economy solutions – for example, in the areas of packaging, construction products, electrical and electronic devices, vehicles and commercial waste (key data for KuRT: 21 projects in the concept phase, 4-5 collaborative research projects, and 1 networking and transfer project are planned for the implementation phase; funding of 23 million euro; to run in the period 2021 – 2028).

Globally, packaging accounts for far and away the largest share – about 60 % – of plastic waste. In Germany, only a small portion of plastic materials are actually managed in circular economies, in spite of high recycling/recovery rates. The funding measure "AI application hub for plastic packaging" ("KI-Anwendungshub Kunststoffverpackungen") is aimed at achieving significant improvements in recycling of plastic packaging via use of artificial intelligence (AI). It is the first effort to take account of the entire value-chain cycle, from design – to production – to collection and sorting – and to recycling and reuse (key data for AI application hub for plastic packaging: 2 innovation laboratories with a total of 51 partners from the areas of industry, science and society, funding of 28 million EUR, industrial contribution of 7 million EUR, to run from 2022 to 2025).

The "KMU-innovativ" programme for funding cutting-edge research by SMEs, a BMBF funding measure, was described in previous National Communications. It is being continued in the current reporting period.

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 CO_2 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 2016, 25 collaborative research projects have been funded, with federal funding of about 28 million EUR. No further submission dates are planned.

The BMBF funding measure “Avoidance of climate-relevant process emissions in industry” (“Vermeidung von klimarelevanten Prozessemissionen in der Industrie” – KlimPro-Industrie) is aimed at supporting German basic materials industries in developing zero-carbon processes and process combinations, and in putting them into practice in the medium-to-long term. To this end, new technologies and/or technology combinations that contribute to direct avoidance of GHG emissions in industry are to be developed and applied on a model basis. The effort is to include study of significantly innovative new approaches, from application-oriented industrial basic research, and assessment of the long-term potential, in terms of feasibility, for implementation of relevant new technologies in industry, taking account of necessary infrastructure investments and cost-effectiveness aspects.

Carbon dioxide can also be used as a raw material. When CO_2 is used as a substitute for fossil-based raw materials, it provides twofold CO_2 savings – by being used directly, and by taking the place of fossil-based raw materials with large carbon footprints. In 2009 – 2016, the BMBF has already invested about 100 million EUR in funding research and development in this thematic area (the funding measure “Technologies for sustainability and climate protection – chemical processes and utilisation of CO_2”) (“Technologien für Nachhaltigkeit und Klimaschutz – Chemische Prozesse und stoffliche Nutzung von CO_2”). With this effort, Germany is taking a leading role in this technology area. From September 2016 to the end of 2019, in the framework of the follow-on funding measure “CO_2Plus – Utilisation of CO_2 to broaden the raw material base” (“CO_2Plus – Stoffliche Nutzung von CO_2 zur Verbreiterung der Rohstoffbasis”), a total of 13 projects were funded, with a total of about 17.5 million EUR. Since 2019, in the framework of the funding measure “CO_2 as a sustainable source of carbon – pathways to industrial application (CO_2-WIN)” (“CO_2 als nachhaltige Rohstoffquelle – Wege zur industriellen Nutzung (CO_2-WIN)”), innovative approaches to CO_2 utilisation have been pursued further – and, to some extent, scaled up to the demonstration level. The 15 collaborative research networks involved in this effort are receiving total funding of about 30 million EUR. The effort is focussing especially on the following three areas:

- CO_2 separation; chemical and biotechnological CO_2 transformation
- Electrolysis and photocatalysis
- CO_2 mineralisation.

The BMBF is funding the further development of systems that separate CO_2 out of the atmosphere, and utilise it as a raw material for synthetic fuels or plastics, also in the framework of the hydrogen lead projects and the P2X Copernicus project. The Carbon2Chem project is developing a CCU approach for producing valuable input products for fuels, plastics or fertilisers from waste gases from steel production. The process has now reached a

level of technical maturity that will permit planning and implementing of pilot plants for production of industrially relevant quantities of Carbon2Chem methanol. Plans call for the technology to be transferred to other sectors with CO_2 point sources, such as cement plants and waste incineration plants.

8.2.5.7 Climate change mitigation in the buildings sector

The “Building the Energiewende energy system transformation” (“Energiewendebauen”) research network facilitates networking among science and industry experts, regarding the thematic area of buildings and neighbourhoods, and it brings together the BMWK’s relevant activities within the 7th Energy Research Programme. The projects of the interdepartmental research initiative “Solar construction / Energy-Efficient Towns” (“Solares Bauen / Energieeffiziente Stadt”) (BMWK/BMBF) of April 2016 will be continued until the end of 2024. In addition, the BMBF is supporting activities in the “buildings and neighbourhoods” thematic area with is supporting within the 7th Energy Research Programme. This is occurring, for example, in the Wärmewende Nordwest (“transformation in the heat sector, for the northwest part of the country”) project, aimed at advancing relevant new techniques for refurbishment and digitalisation.

8.2.5.8 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 Germany, in recent years, in reducing this sector’s CO_2 emissions. The German government is therefore pooling its efforts in the field of electromobility, in which the BMWK, BMBF, BMDV and BMUV are all involved. The BMDV’s electromobility funding guideline, which has been in place since 2015, comprises three pillars. These include procurements of municipal and commercial fleets of electric vehicles; preparation of concepts that can serve as a strategic basis for fleet conversions; and research and development projects. To date, 28 research and development projects for support of the electromobility market have been funded. Funding for research and development has a big-picture focus. It takes account of the entire electromobility system, from vehicles to charging infrastructures to network integration. Additional 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 cars are making other vital contributions to research. The BMWK is pooling its activities in this field in the New Vehicle and System Technologies programme.

The Mobility2Grid project funded by BMBF is examining sector coupling between mobility and renewable energy. A crucial feature of this is openness to technological alternatives. The BMBF is therefore also funding research into synthetic fuels that can serve as intermediate storage media for renewable energy. For example, in the framework of the Carbon2Chem project, fuel will be produced for an inland vessel that will be converted, within the project, to run on methanol. In addition, within the framework of the Federal Climate Action Programme 2030, the BMBF is funding research and development on all links of the process chain for producing and using synthetic fuels – right up to and including the stage at which they are combusted in engines. Also, it is funding supporting research into the relevant systems (the NaMoSyn research cluster – Sustainable Mobility with Synthetic Fuels). The central goals of the project include the phasing in and industrial production of oxymethylene ethers (OME), which are synthetic fuels that burn soot-free, have a small carbon footprint and can significantly reduce local emissions, such as NOx and particulates, in urban

traffic settings. The fuels are being studied in terms of their properties and sustainability and, in the process, the basis for their market launch, including definition of standards, is being created. This project, along with projects for CO_2 capture from air, and for its use for production of climate-neutral kerosene, is providing significant impetus for climate action in the transport sector.

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 the BMWK's cross-programme research initiative "Energy Transition in the Transport Sector: Sector Coupling Through the Use of Electricity-Based Fuels." This effort, launched in the spring of 2017, is focussed on cross-sectoral approaches to alternative electricity-based fuels; on integrating new technologies into the energy sector; and on researching and developing special applications in maritime systems.

The BMEL's funding for research into the efficient use of fuel in agriculture is also making an important contribution to climate change mitigation. The BMEL's "Renewable Resources" funding programme is funding research projects aimed at developing and validating innovative methods and technologies for producing advanced biogenic fuels, especially for the purpose of reducing GHG emissions.

The BMDV is supporting research and demonstration projects that address the technical challenges involved in producing renewable fuels. It is doing so via a technologically open-ended (i.e. without preference for certain technologies) funding guideline for the further development of renewable fuels, and via competitively structured funding for the construction and operation of a development platform for electricity-based liquid fuels.

Urban areas are an important focus of mobility research. In its "Research Programme on Urban Transport ("Forschungsprogramm Stadtverkehr" – FoPS), the BMDV is investing 4 million EUR annually in contract research on ways of improving transport in urban areas. Also, the BMDV Network of Experts is carrying out research projects that are exploring options for developing renewable energies for the transport sector, as well as transport infrastructure that can help reduce GHG emissions.

In 2018, the BMBF published its research agenda on "Sustainable Urban Mobility," on the basis of two agenda processes carried out in 2017/2018. The research agenda is aimed at advancing the sustainable transformation of mobility systems in both urban and rural areas. In a resulting competition held in 2020, "MobilitätsWerkStadt 2025" ("Mobility Workshop 2025"), some 50 municipalities developed innovative mobility concepts. As of 2021, 14 of the municipalities, working in real-world laboratories, in cooperation with stakeholders and citizens, are implementing their concepts. Also, since 2020 twelve interdisciplinary and transdisciplinary research projects, working within the "MobilitätsZukunftsLabor 2050" ("Future Mobility Laboratory 2050") funding measure, are developing new, systemic solutions for sustainable, low-emissions mobility. In the process, they are developing and improving systems-based and orientational knowledge, in order to create a solid foundation for ongoing innovation / transformation management. These two funding measures are complemented by a Japanese-German cooperation project on connected and automatic driving (CADIA), and by the research projects "Bürgerlabor Mobiles Münsterland" ("Citizens' Laboratory for a Mobile Münsterland") (BueLaMo) and "Mobilität und Corona" (Mobility and the Coronavirus") (MOBICOR). Currently, a pilot project on sustainable transformation of regional innovation areas, with an emphasis on mobility, is being planned.

8.2.5.9 Carbon capture and storage

In the power station sector and in energy-intensive industries with high process-related CO_2 emissions, carbon capture and storage (CCS) can be regarded as an option for achieving the target of reducing CO_2 emissions by 80–95 %.

Research on geological CO_2 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, divided into site-independent and site-specific research. The site-independent research sought to answer basic questions about geological CO_2 storage. The site-specific research explored and operated specific test-storage facilities.

In the framework of the site-independent research dealing with basic issues, the BMBF supported 32 projects, with funding of over 30 million euro. The 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 28 million euro. Funding for research projects on geological CO_2 storage largely ceased upon conclusion of the special GEOTECHNOLOGIES programme at the end of 2014. The BMBF stopped its funding on this topic completely at the end of 2016.

The Federal Ministry for Economic Affairs and Climate Action (BMWK) funds application-oriented research, and pilot projects on carbon capture, within its energy-research funding programme.

8.2.5.10 Negative emissions (Carbon Dioxide Removal, CDR)

Negative emissions refer to active removal of CO_2 from the atmosphere, a process known as "Carbon Dioxide Removal" (CDR). CDR includes naturally based and technologically oriented approaches and methods for removing CO_2 from the atmosphere and then storing it permanently in underground geological formations, in biomass, oceanic storage facilities or long-lived products.

The scenarios presented in the IPCC's reports make it clear that meeting the 1.5°C target will necessitate using CDR on a considerable scale. CDR methods for offsetting unavoidable residual emissions, and for reversing a possible temperature overshoot, have not yet been adequately studied, however. The BMBF has recognised these challenges. In 2021, it initiated two precautionary research measures aimed at reviewing large-scale onshore and offshore CDR scenarios in terms of their possibilities, feasibility and effectiveness. In addition, plans call for research into the relevant legal, ethical and regulatory requirements; into governance and acceptance issues; and into potential socioeconomic and ecological impacts. These efforts – which are transparent, and unbiased as to technologies – will provide the necessary foundational knowledge for political decisions in this area.

The research measure *CDRterra* is studying technically based and naturally based CDR methods, also with a focus on their combined effectiveness. As the questions of what quantities of CO_2 could be removed, and what form of long-term CO_2 storage is best, are studied, it will also be necessary to develop and assess suitable policy instruments, in a process that includes public participation and the involvement of civil-society stakeholders. The BMBF is funding 10 collaborative research projects, with a total of about 21 million EUR.

In the framework of the German Marine Research Alliance (DAM), a research mission on marine carbon storage has been initiated. The CDRmare research mission is studying

whether, and to what extent, the oceans could play a significant role in capture and storage of atmospheric CO_2. In addition, it is exploring relevant interrelationships with the marine environment, the Earth system and society; the potential impacts on these areas; and suitable approaches for monitoring and measuring (and carrying out relevant accounting) carbon storage in the ocean, in a changing environment. The BMBF is funding 6 projects, with a total of 27 million EUR.

The BMBF's basic research policy commitment in this area is aimed at providing a reliable knowledge base, and at tapping potential for innovation, with a view to achieving successful, effective, socially and ecologically responsible and economically promising CO_2 removal (in Germany and internationally). In the process, it is making a clear distinction between emissions reduction (via climate action) and CO_2 removal: While CDR may be needed for achievement of climate targets, it must function as a complement to emissions reductions. It cannot take their place. The priority clearly lies on emissions reductions.

8.2.6 International cooperation

The federal government expressly holds the position that assumption of global responsibility is a basis for implementing the guiding principle of sustainable development (cf. also Chapter 6).

8.2.6.1 Research for the sustainable development of the cities of tomorrow

According to estimates of the World Bank, cities will account for 80 % of the future growth of developing and emerging countries. While this growth will bring benefits for companies and urban populations, it will also create new challenges: Cities will have to find ways of providing, maintaining and financing their technical infrastructures (such as housing, transport systems, energy system, water supply system, etc.) and social infrastructures (such as health care, schools, jobs, etc.).

In its funding priority "Sustainable Development of Urban Regions" (SURE), the Federal Ministry of Education and Research (BMBF) is supporting projects in rapidly growing cities and urban regions in developing and emerging countries. The focuses of this effort include a) technological solutions oriented to improving energy and resource efficiency, to reducing CO_2 emissions, and to developing concepts for sustainable new infrastructure systems (energy supply, transport systems, etc.); and b) development of societal innovations for management of resulting changes in living conditions.

Also, the SURE funding measure is aimed at a) developing and testing – in close cooperation between scientists and real-world users – locally adapted strategies that help improve ecological factors and enhance cities' resilience, and b) providing impetus for lasting implementation of the strategies. In the measure's first phase, ten million euro was provided for support of definition projects in China and in the southeast Asian countries Indonesia, Cambodia, Laos, Myanmar, Philippines, Thailand and Vietnam, with each project running for 18 months. Currently, a four-year funding phase is underway, supporting additional research and development relative to the solution strategies, in a total of eleven projects. It has a funding volume of 28 million euro. A subsequent two-year phase will focus explicitly on the applying the results.

8.2.6.2 Regional research and service centers for climate change and adapted land management in Africa:

Together with partners from eleven 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. The two initiatives, SASSCAL (Southern African Science Service Centre for Climate Change and Adaptive Land Management) and WASCAL (West African Science Service Centre for Climate Change and Adapted Land Use), are aimed at supporting the regions, which are strongly affected by climate change, in building scientific structures.

The purposes of the effort are to support developing and emerging countries in Southern and West Africa in developing their own competencies and capacities in applied research and development on climate change adaptation, and in developing and implementing adapted land-management practices (covering areas such as water availability, land use and ecosystem services). The centers will focus on applied research, and they will also provide advising services for public-sector and private-sector decision-makers in their regions. One of their most important tasks will be to train young scientists from African countries.

The BMBF research programme “Science Partnerships for the Adaptation to Complex Earth System Processes in Southern Africa – SPACES II” is building additional research partnerships for assessment of complex Earth-system processes in the Southern African region. Their research is expect to deepen our knowledge about the functioning of Earth-system processes in Southern Africa. That, in turn, will provide a basis for identifying options for addressing natural changes and anthropogenic influencing factors, and thereby for developing and deriving the necessary scientific data for formulation of science-based recommendations, relative to Earth-system management, for policymakers. The SPACES programme is supporting by a capacity-building programme designed in close cooperation with scientists involved in SPACES projects.

8.2.6.3 Water security in Africa (WASA)

Water security is the basis for sustainable development in Africa. Africa has a pressing need for innovative water technologies, water infrastructures adapted to climate change (including both droughts and floods), and forward-looking management concepts. The interdepartmental programme “Water Security in Africa (WASA),” focussed especially on research and education, has been established as a result of the federal government's round table discussions on the topic cycle “Creating perspectives in Africa” (“Perspektiven schaffen in Afrika”). At present, 13 cooperation projects are conducting research in the programme’s initial phase.

The WASA programme was developed via a consultation process, and in cooperation with African and German scientists and experts in the field. The participating institutions on the German side include the Federal Ministry of Education and Research (BMBF; as lead institution), the Federal Foreign Office (AA), the Federal Ministry for Economic Cooperation and Development (BMZ), the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV), the Federal Ministry of Food and Agriculture (BMEL), the Federal Ministry for Digital and Transport (BMDV) and the Federal Ministry for Economic Affairs and Climate Action (BMWK), along with their subordinate institutions. WASA is part of the BMBF’s “Research for Sustainability (FONA)” strategy.

WASA stands for innovative forms of partnership cooperation with Africa, aimed at strengthening the science, economic and civil society sectors. Its central overall focus consists of making contributions toward the achievement of the UN's Sustainable Development Goals (SDG).

In an initial phase, the WASA programme is operating in southern Africa. This phase is being financed via a BMBF call for proposals. WASA is organised into three overarching thematic areas: Sustainable water resources management; Water infrastructure and water technology; and Hydrological forecasts and predictions.

8.2.6.4 The CLIENT II funding priority – International Partnerships for Sustainable Innovations

Since 2010, the Federal Ministry of Education and Research (BMBF) has funded a programme entitled International Partnerships for Sustainable Technologies and Services for Climate Protection and the Environment (CLIENT). In the period from 2010 to 2017, the programme has implemented 31 bilateral research and development projects (with total funding of approximately EUR 60 million) with emerging economies and developing countries.

A subsequent call for proposals, "CLIENT II – International Partnerships for Sustainable Innovations" (December 2015), is designed to build on CLIENT. In addition to having a sharp thematic and regional focus, CLIENT II 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 projects being funded in this effort are designed to provide impetus for environmental-pollution reductions in the partner countries; smart, efficient utilisation of natural resources; a reliable, clean and affordable energy supply for all segments of the population; and contributions to global action and adaptation to climate change and natural risks. The overall aim of the effort is to develop and implement innovative, sustainable strategies, in seven key thematic areas[204], for addressing pressing challenges in the partner countries.

Along with research and development projects, the measures being funded include preparatory measures – definition projects aimed at assessing the potential of a solution to be developed. Networking of research projects – both with each other, and with stakeholders in the partner country – is being supported via accompanying projects and regional, in-country project offices, and by a central transfer and support project. Since March 2017, over 70 international collaborative research projects have been supported in the CLIENT II framework, with funding totalling more than 140 million EUR.

8.2.6.5 Integrating research activities into international programmes

The 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 to be involved in organising international cooperation.

The German IPCC coordination office, which was set up by the BMBF and the Federal Foreign Office (AA), works to ensure that results of German climate research enter into the IPCC process and the Sixth 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

[204] Resource efficiency and circular economy, water management, climate protection / energy efficiency, adaptation to climate change, land management, sustainable energy systems and natural hazards

Support Unit based at the Alfred Wegener Institute for Polar and Marine Research. In addition, the BMBF promotes quality assurance by providing German coordinating lead authors (CLAs) of IPCC reports with scientific assistants.

Also, the BMBF and the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) have set up the German IPBES coordination office, which backs the integration of technical expertise into the work processes of the IPBES World Biodiversity Council (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) and supports essential political consultation and decision-making processes at national level.

8.2.6.6 The 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 provides a coordinated pan-European platform where strategies, instruments, resources and stakeholders at the national and European levels 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 key challenges that JPI Climate addresses are derived from its Strategic Research and Innovation Agenda (SRIA): Understanding the processes and consequences of climate change; improving knowledge on climate-related decision-making processes and measures; and researching sustainable societal transformation in the context of climate change. It also includes a strategic mechanism: Connecting people, problems and solutions in a systemic approach.

Joint Programming Initiative Climate is a cooperative effort that currently involves a total of 19 member states. The JPI Climate Secretariat is located in Brussels.

8.2.6.7 FACCE

The Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI) is an association of currently 24 countries. The participants have set themselves the goals 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 is pursuing this goal with a strongly transdisciplinary research approach, encompassing economic and social aspects in addition to scientific ones.

Alignment of national programmes, and input from multiple actors and interest groups, play an important role in it.

The integrated FACCE-JPI strategic research agenda defines four core research themes:

1. An agricultural sector that contributes to climate neutrality.
2. Sustainable & resilient agriculture.
3. Nutrition-sensitive agricultural production for food security.
4. Trade-offs and synergies between food production, ecosystems and climate.

Since 2012, Facce-JPI members have carried out a total of 18 joint research activities, with funding amounting to about 250 million EUR (as of 12 Oct. 2022).

The BMEL and the BMBF are jointly represented within FACCE-JPI. In cooperation with other member states, they operate the secretariat, which has a decentralised organisational structure. Germany has the deputy chair.

8.2.6.8 The Joint Programming Initiative "Healthy and Productive Seas and Oceans" (JPI Oceans)

JPI Oceans is an alliance of 19 member-countries and one associated member-country, carries out research, via Joint Actions, on pressing research questions. Currently, it is carrying out joint actions in the areas of, inter alia, "Blue Carbon," "Ocean Carbon Capacities" and "Science for Good Environmental Status." Also, it studies climate-relevant focus areas in close cooperation with other JPIs, such as Climate and Water. Further information: https://jpi-oceans.eu/en/joint-actions

8.2.6.9 The Joint Programming Initiative "Water Challenges for a Changing World (Water JPI)"

The key aims of European water-resources policy include protecting water ecosystems; increasing resource efficiency; and developing future-proof water technologies, infrastructures and systems for increasing resilience to climate change. Water JPI supports these aims by defining relevant joint strategies and research focuses. It is an alliance of 20 full member countries, five associated partner countries and four observer countries. Its national and regional research programmes are coordinated via a) implementation of a jointly developed strategic research and innovation agenda and b) execution of joint activities. Its priority research areas include ecosystems, health and well-being, water value and water use and sustainable water-resources management.

8.2.6.10 The European Partnership "Water Security for the Planet (Water4All)"

The core aim of the European Water4All partnership is to safeguard a lasting, reliable water supply. Its basic approach, which is multinational, multi-faceted and cross-cutting, takes account of political, ecological, economic, technological and societal requirements. Through 2030, the Partnership plans to carry out research aimed at boosting water systems' resilience and ability to adapt to global changes, and at building and strengthening a green, resilient and competitive Europe. A total of 79 institutions, from 31 countries, and three European networks, are participating in the Water4All Partnership.

The Water4All Partnership was launched in 2022, under the auspices of the EU's Horizon Europe programme.

8.2.6.11 European Partnership Driving Urban Transitions to a Sustainable Future (DUT), and the Joint Programming Initiative (JPI) Urban Europe

The BMBF and BMWK are involved in the European Partnership "Driving Urban Transitions to a Sustainable Future" (DUT), in the research areas sustainable mobility ("15 Minutes City") and energy transformation ("Positive Energy Districts"). The partnership, a European research and innovation programme for sustainable urban development, has a long-term time frame. With an initial seven-year operational period, it was launched in 2022, as a cooperative effort bringing together over 60 public and private partners, from a total of 27

countries. It is being co-financed by the EU. DUT is seeking to enable municipalities, companies and private citizens to implement global strategies in the context of local actions, with a view to making urgently required urban transformations proceed as sustainable development.

In addition, in the framework of “JPI Urban Europe,” a European initiative for joint programme planning, the BMBF is participating in the three-year funding measure “Urban Accessibility and Connectivity” (ENUAC), which was launched in 2021. The measure is aimed at promoting safe and reliable, accessible and affordable transport systems, and at reducing adverse climate and environmental impacts.

8.3 Systematic observation and data management

The condition and development of each individual component of the climate system need to be observed; this continues to be a pressing need. In addition, it is important to gather information about the natural systems and structures on which people depend and that are being affected by climate changes or other types of global changes. For this reason, Germany continues to expand its support for the Global Climate Observation System (GCOS).

Earth observation systems provide such observation and information-gathering resources. They make use of both in-situ and remote observation procedures. Remote observation is carried out by ground-based, airborne, waterborne and space-based systems. To obtain a complete picture of the natural systems involved, one must integrate findings from all available observation procedures. To be able to describe the condition and development of the climate system, one requires a complete (as complete as possible) picture, made reliable though long-term observation of the essential climate variables (ECVs) that have been internationally identified. A more-detailed description of Germany’s contributions to the global climate-observation systems is provided in a separate report[205]. The internationally defined ECVs serve as orientation in determination of the key climate variables for Germany.

Germany’s GCOS National Coordinator, who is sited within Germany's National Meteorological Service (Deutscher Wetterdienst, DWD), serves 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 has 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, and since then 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. This 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 major research institutions continue to participate extensively in international monitoring networks observing a) the atmosphere (World Weather Watch (WWW) and Global Atmosphere Watch (GAW), both of which are WMO

[205] German Meteorological Service (Deutscher Wetterdienst 2022): www.gcos.de/inventoryreport)

programmes); b) the oceans (Global Ocean Observing System (GOOS), run by UNESCO's Intergovernmental Oceanographic Commission (IOC)); and land surfaces (Global Terrestrial Observing System (GTOS), run by the Food and Agriculture Organization (FAO)). All the climate observation components of these systems together make up GCOS. WMO, IOC, the International Science Council (ICS) 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 the funding of the international GCOS secretariat's activities and operation.

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 that 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. As a result of increased use of automatic stations, data are now available in a time resolution of one to ten minutes. The number of stations operated by DWD depends on the particular ECV involved. It currently has about 2,400 observation stations for precipitation (as of 1 Oct. 2022).

With a view to extending the time frame for use of 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 our understanding of the climate system.

DWD operates national reference stations at which traditional and automated measuring processes are operated in parallel, in order to identify systemic 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[206]. On behalf of the World Meteorological Organization (WMO) Commission for Basic Systems (CBS), DWD also runs one of the world's nine CBS Lead Centres for GCOS.

[206] German Meteorological Service (Deutscher Wetterdienst 2022) https://www.gsnmc.dwd.de

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),[207] 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 undergo strict quality control. Since the beginning of 2008, Germany (AWI) has also been responsible for operating the World Radiation Monitoring Center (WRMC).

Satellites have become an indispensable source of the information needed to identify and assess 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 it operates – for example, at DLR – the World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT). 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. With its new long-term satellite systems, Meteosat Second Generation (MSG) and Meteosat Third Generation (MTG) (both of which are geostationary) and MetOp and MetOp SG (first- and second-generation Meteorological Operational satellite) (both in polar orbit), EUMETSAT makes an important contribution to long-term atmospheric observation for climate monitoring, using instruments that previously could be made available only for short periods of time on research satellites.

For more than 20 years now, EUMETSAT has operated a network of Satellite Application Facilities (SAFs), in order to provide satellite products for a range of different thematically grouped applications. Their purpose is to develop, derive and archive application-oriented satellite products and deliver them on an ongoing basis.

The development and generation of specialised products for observing the climate system is carried out jointly by EUMETSAT and the partners in the European CM SAF (Satellite Application Facility on Climate Monitoring), which is operated by seven national meteorological services/institutions in Europe, with DWD as lead agency. CM SAF has broadened the focus of its activities in recent years and now also delivers high-quality, regional and global long-term climatologies of satellite-derived parameters (such as on solar and thermal radiation, population, humidity distribution and global precipitation). To some extent, the climatologies now also cover the current WMO reference period, 1991-2020. Operational data from CM SAF thus support the tasks of the WMO Regional Climate Centre (RCC) network in monitoring the climate in Europe[208]. With these activities, CM SAF, working on behalf of EUMETSAT and headed by DWD, occupies a leading position in Europe.

[207] Deutscher Wetterdienst (7 Oct. 2022) https://www.dwd.de/EN/research/international_programme/gruan/.
[208] http://www.rccra6.org/rcccm

Various facilities have been set up in Germany as part of the European Integrated Carbon Observation System (ICOS) research infrastructure: central laboratories, an atmospheric measurement network (currently, with nine stations), and ocean and ecosystem locations for measuring the long-lived climate gases CO_2, CH_4, and N_2O and the ECV precursor CO. The national measurement networks and central facilities deliver high-quality data, standardised across Europe, which are used by scientists in model validation (for example, the Copernicus Atmosphere Monitoring Service (CAMS)) and inverse modelling, and which will also contribute to services such as WMO's Integrated Global Greenhouse Gas Information System (IG3IS), by being used in combined form with other observation data and model systems being developed in the Integrated Greenhouse Gas Monitoring System for Germany (ITMS). ICOS is an important element in the system of verifying emission reductions in Europe.

ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure), a European research infrastructure similar to ICOS, is currently being created for study of aerosol parameters and aerosol and ozone precursors, i.e. short-lived climate forcers (SLCFs). In this infrastructure, Germany is aiming to play an important role with observational networks (DWD, UBA, other research institutions) and central facilities connected with calibration laboratories. ACTRIS will also play an important role in monitoring emission reductions and in improving our understanding of relevant processes.

Various institutions in Germany also participate in the Satellite Application Facility on Atmospheric Composition Monitoring (AC SAF) (SAF).

HALO (High Altitude and Long Range Research Aircraft) has taken aircraft-based atmospheric research to a new level. The aircraft, which was built for DLR by Gulfstream, was delivered following extensive test phases. It has been available for use in Germany's research programmes since 2012. 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 communities 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 the transition zone between the troposphere and stratosphere. In addition, DLR's CHARM-F instrument supports CO_2 and methane observations. German environmental and climate researchers have already carried out numerous missions with the HALO system.

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), the Center for Earth System Research and Sustainability (CEN), DWD, GEOMAR, 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. For over 30 years, the Federal Maritime and Hydrographic Agency (BSH) has operated the MARNET measuring network, which currently has 10 stations in the North Sea and Baltic Seas. Germany provides about 40 to 50 ARGO drifters a year, and within WMO's Voluntary Observing Ship (VOS) programme equips a fleet of about 354 merchant ships with meteorological instruments (as of:

11 July 2022). The Federal Maritime and Hydrographic Agency (BSH) is the 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,[209] 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[210]) and the Global Terrestrial Network for River Discharge (GTN-R). A third international data center, the International Soil Moisture Network (ISMN, developed by TU Wien), is currently being transferred to BfG and ICWRGC. There, in January 2023, it will begin operations for observation of global soil moisture. Coordination of the GTN-H is also carried out in Germany, by the International Centre for Water Resources and Global Change (ICWRGC), which is sited at the Federal Institute of Hydrology (BfG) in Koblenz. 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, TerraSAR-X and TanDEM-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 to the observation stations operated by Germany in other countries.

The Geodesy and Glaciology group (KEG) 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 are regularly made available to international data centres such as the World Glacier Monitoring Service (WGMS[211]) and the National Snow and Ice Data Center (NSIDC[212]).

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.[213]

[209] https://www.bafg.de/GRDC/EN/Home/homepage_node.html
[210] https://www.gtn-h.info/
[211] https://http://www.geo.unizh.ch/wgms.ch/
[212] https://nsidc.org/ http://nsidc.org/index.html
[213] https://www.permanet-alpinespace.eu/ http://www.permanet-alpinespace.eu

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 the Global Terrestrial Network for 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 connection with 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 that are part of the ESA Earth observation programme, such as Aeolus, SMOS and CryoSat-2 – and, soon, BIOMASS and EarthCare – are 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 in it. German institutions such as DWD, DLR, and IUP Bremen have assumed responsibility for deriving atmospheric GCOS variables in this context. The preparations for a follow-on programme as of 2023 (CLIMATE-SPACE) have now been completed. In addition to continuing the CCI, that programme will focus especially on the Paris Agreement goals and on study of the “tipping points” in the climate system.

With the Copernicus programme, which has been jointly initiated by ESA and the EU, Europe is ensuring long-term continuity for many other climate-related observation efforts, especially satellite observations. The first phase of the third part of the relevant ESA programme was adopted at the end of 2012. It will complete the development of the Copernicus Space Component by about 2020. Currently, an expanded programme is being established that will include missions for monitoring the carbon cycle (CO2M; launch at the end of 2025), the cryosphere and the land surface (several missions as of 2028). Also, the next generation of the existing Sentinel satellites is being established. The EU is responsible for operating the systems and setting up the services. Alongside GALILEO, the Copernicus programme 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 have been used since 2007 to detect ice sheets, for example, as well as many other climate parameters. The TanDEM-X mission has been used to generate a global elevation model that serves as an important basis for many climate-related studies. With the help of data collected by NASA’s GEDI mission, on the ISS, studies of global biomass distribution are being carried out.

Higher carbon dioxide emissions and changes in land use have led to a rapid rise in CO_2 in the atmosphere in recent years (see report by the Global Carbon Project 2016). CO_2

monitoring will also be an important task for Earth observation systems in future (such as the Integrated Carbon Observation System (ICOS)[214]).

Under its renewable resources funding programme, the Federal Ministry of Food and Agriculture (BMEL) has funded the development of the Global Risk Assessment Services (GRAS) tool.[215] GRAS, an online tool for the establishment and review of sustainable supply chains based on use of raw materials from agriculture and forestry, also provides information about ecological and social sustainability. It now covers 62 countries in which the risk of losses of soil organic carbon stocks and of biodiversity, as a result of non-sustainable agricultural production, are especially high. Users will be able to access the system to obtain information about areas of interest, including information about biodiversity, carbon stocks, land-use history and social aspects (such as food security, indigenous population): 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.

GRAS provides access to data of the latest generation of satellites. The central elements of GRAS include time-series analyses, of satellite images, that can reveal land-use changes. As a new option, a fire warning system has been integrated that informs users, via email, and within 24 hours, regarding fires that have emerged in their observation areas. In the countries covered by GRAS, fires in rural areas are often indicators for slash-and-burn practices that are followed by land-use changes. In addition, a method has been developed for taking account of the production sites of small farmers and integrating them within international, certified supply chains. Via a tracking app, users will be able to trace supply chains from end products back to individual small farmers and the fields they cultivate. The app is available for additional pilot applications with market participants. Also, the information it provides about social issues has been considerably expanded.

GRAS is a valuable instrument for sustainability certification in a range of different areas, including bioenergy, bio-based products and foods and animal feed. It is not used only for certification, however. Large brand owners use it, for example, for risk assessment of their suppliers and for monitoring purposes. Banks use it in the context of loan decisions. In the forestry sector, for example, GRAS can be used to determine carbon stocks and detect disasters. GRAS also makes an important practical contribution to implementation of the Supply Chain Act (Lieferkettengesetz).

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 (GDIDE) 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.

Provision of environmental data in Germany is regulated by the Spatial Data Access Act (Geodatenzugangsgesetz) of 10 February 2009.

[214] http://www.icos-infrastructure.eu/
[215] http://www.gras-system.org/

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, in the Maritime Data Center (MDZ), and it operates a node for the Marine Data Infrastructure Germany (MDI-DE), which provides official marine data for the coastal zone.

Germany's Federal Motor Transport Authority is one of the most important data sources for transport policy and infrastructure planning, and for research on the transformation process underway in the road traffic sector. Since spring 2022, its research data center has provided anonymised micro-data files for scientific analyses on the structure and development of the vehicle fleet, consisting of more than 66 million motor vehicles and motor-vehicle trailers.

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 it supports data searches and use. 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 of the federal/Länder monitoring programme for the marine environment of the North Sea and the Baltic Sea. MUDAB is operated by the German Federal Institute of Hydrology in Koblenz.

The Deutscher Wetterdienst (DWD) runs the National Climate Data Centre (NKDZ), which houses the meteorological-observation data 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. The networks of meteorological monitoring stations collect data on specific physical and chemical topics of interest. These national data are supplemented by global data provided by international data centers: They include GPCC, which carries out global precipitation analyses; CM SAF, which provides climate-monitoring products derived from satellite data, and satellite-based climatologies; and the Global Collecting Centre (GCC), which provides global maritime data. The DWD's Climate Data Centre (CDC) has established a central portal that provides access to all this data, and that is continuously being improved.

In addition to operating 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 (with DWD monitoring precipitation data, and JMA monitoring temperature data) from stations in the GCOS Surface Network (GSN) (cf. 8.3.1). With external support in the field of atmospheric physics, the German Environment Agency is setting up one of three centres worldwide for data quality assurance and control within the Global Atmosphere Watch (GAW) programme.

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 ensures that scientific institutions and major research institutes in Germany are able to access the data.

Paleoclimate databases are operated by the Alfred Wegener Institute for Polar and Marine Research (AWI) (with the PANGAEA® information system, which includes the PKDB paleoclimate database at the University of Hohenheim) and the German Research Centre for Geosciences (GFZ).

Other examples of information systems providing data on the state of the environment in Germany include the landscape information system (LANIS) of the Federal Agency for Nature Conservation; 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 resources. The data it provides are used in virtually every supraregional and national development and consulting project related to land use and land-use changes. The data are updated and quality assured on an ongoing basis, and harmonised with other countries' data 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 of satellite-collected data on climate variables. They include data systems within relevant ground segments, such as those of the ERS-1/2 and METOP satellite systems; a World Data Center for Remote Sensing of the Atmosphere (WDC-RSAT); and efforts to develop algorithms for study of climate variables. Users can obtain DLR's products on the internet, via DLR's EOWEB.

The Julius Kühn Institute (JKI) has set up a Research Centre for Agricultural Remote Sensing (FLF). In doing so, it is responding to the growing importance and potential of remote-sensing applications for the derivation of satellite-monitored climate variables in the context of agriculture.

Two international data centres for data relevant to the global hydrological cycle have been set up in Germany as part of WMO's World Climate Research Programme (WCRP). The centres, of which both are key components of GCOS and GEOSS, include:

- 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), in cooperation with the Federal Maritime and Hydrographic Agency (BSH).

Further information about this area is available in the publication “Die deutschen Klimabeobachtungssysteme. Inventarbericht zum Global Climate Observing System (GCOS)”[216] of Deutscher Wetterdienst.

8.3.7 Support for emerging and developing countries

German contributions to supporting emerging and developing countries in establishing and operating observation systems and systems for data management and climate monitoring are described in the following chapter.

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 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.

In March 2017, the project “Improved Climate Services for Infrastructure Investments” (IKI-CSI), which is aimed at improving the use of climate services in certain selected countries, was launched. It is being financed with funding from the International Climate Initiative (ICI) of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV). The project is scheduled to run until October 2023.

Agencies such as DWD do not have their own funds that would enable them to provide direct support to partner meteorological services in emerging and developing countries. Germany has provided financial support for the international GCOS Secretariat for a number of years now.

Relevant activities relating to support for emerging 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.

[216] www.gcos.de/inventoryreport

9 Education, training and measures to raise public awareness

9.1 Basic orientation of education policy and public relations for climate action

In light of the multi-layered ecological, economic and societal challenges posed by climate change, action-oriented educational programmes are needed that, in creative ways, impart and promote technical, scientific and social problem-solving skills.

Knowledge about the interactions at play in connection with climate change does not by itself lead to effective action aimed at transformative climate and environmental action that reshapes society in suitable ways. To spark such action, a diverse range of opportunities for putting climate-change knowledge into practice, and building it further, is needed.

The educational programmes of the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) in this context apply the principles of Education for Sustainable Development (ESD), within the meaning of action- and participation-oriented political education.

As political education, Education for Sustainable Development promotes dialogue and creative, critical thinking, and it imparts orientational knowledge. It relies on participants' willingness to assume responsibility for their own actions, to deal with uncertainties and contradictions, to solve problems and to take a role in shaping a democratic, culturally diverse society.

Its central aims include enhancing opportunities to participate – for children and adolescents. In keeping with the UN's Agenda 2030, issues of social equity, cultural diversity and gender equality also play an important role in this context.

Since 2015, in the framework of German implementation of UNESCO's ESD 2030 programme, a national process for structural enshrinement of ESD in all education sectors has been underway in Germany, under the leadership of the Federal Ministry of Education and Research (BMBF). In 2017, the highest-level steering body for this effort, the National Platform on ESD, adopted the German National Action Plan on ESD. It is being implemented on an ongoing basis. The platform is supported by six forums that are oriented to the education sectors involved (early childhood care and education; technical and vocational education and training; school; higher education; non-formal and informal learning / youth; local authorities), and it works in association with a youth forum, "youpaN." youpaN consists of 30 young people who help make decisions on processes, develop projects of their own and carry out broad-based public relations.

9.2 Programmes for early education, and for primary, secondary and higher education

The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) offers a diverse range of action- / participation-oriented educational materials on the subject areas climate change, climate adaptation and climate protection. While they are aimed primarily at the primary and secondary school levels, they are suitable for all types of schools. The relevant programmes are aimed at educators working on all grades/levels of general education and vocational training, as well as at multipliers working in extracurricular areas. The main emphasis is on online resources available at the

Internet portal www.umwelt-im-unterricht.de. On a biweekly basis, the portal publishes teaching ideas and resources for current environmental issues and events, such as the UN Climate Change Conferences.

The materials and resources may be used for teaching purposes free of charge, and visitors to the site do not have to register in order to access them. Apart from a few exceptions, the content is covered by Creative Commons licenses, and thus users may edit it and distribute and publish it in modified form.

Since 2008, the BMUV's education service https://www.bmuv.de/themen/bildung-beteiligung/bildung has published a monthly newsletter with news on the ministry's activities, and on projects, dates, events and publications relating to the area of education about sustainable development. The education service's central website presents dates, competitions and relevant materials and resources from various areas. As a result, the education service helps promote effective networking and communication in education.

As part of its efforts to promote innovative climate action projects in the framework of the National Climate Protection Initiative (NCI), the Federal Ministry for Economic Affairs and Climate Action (BMWK) funds education projects that help raise awareness for climate issues on the part of both students and teachers. The projects are designed to encourage students and teachers to get involved in climate action – and, ultimately, to help reduce GHG emissions.

As part of its climate action campaign, the BMWK funds the "Energy-saving champ" ("Energiesparmeister") competition, which helps make school staffs, pupils and parents aware of the need to save energy. In addition, each year it bestows awards on the most-innovative, most-creative and most-efficient climate action projects at German schools. A jury selects the best school project in each German Land (state) and honours 16 schools as "Energy-saving champs." Along with a prize of 2,500 euro, each energy-saving champ receives a sponsorship from an industry or society partner who helps support the competition. The sponsorships promote efforts in the area of sustainability, and they help build bridges between different areas of civil society.

In the framework of the Education for Sustainable Development (ESD), the Federal Ministry of Education and Research (BMBF) coordinates the work of the forum's Early childhood education, Schools, Vocational training and Higher education and, in the same framework, offers numerous programmes. In the framework of the Early childhood education forum, a "Reference framework for early childhood education" ("Referenzrahmen für die frühkindliche Bildung") was published. It serves as a framework for practical efforts to establish early childhood education, reliably and effectively, in children's daycare facilities. In the framework of a BMBF-funded project of the "Haus der kleinen Forscher" ("Little Scientists' House") Foundation, ESD courses for educators working in early childhood education are developed and offered.

In the BMBF-funded project "Nachhaltig Lehren Lernen" (an approximation: "Learning how to teach sustainability"), which is being carried out at the Heidelberg University of Education, continuing-education programmes and structures focussing on teacher training relative to ESD are being established at selected higher education institutions in Germany.

The BMBF's funding programme "youstartN" helps young students' firms and startups in implementing sustainability concepts.

ESD plays an important role in the BMBF's Sustainability in Science Initiative (SISI), which funds projects involving higher education institutions, non-university research organisations and students' initiatives (cf. Chapter 8.2.4.1). The aim of the Initiative is to implement

sustainability in the various areas of the science system, using a “Whole Institution Approach.” The successful examples of the efforts carried out within the Initiative include the “n” network’s travelling coaching programme (Wandercoaching-Programm), which teaches students useful ways of making higher education institutions more oriented to sustainability and climate action.

9.3 Public information campaigns

The federal government’s Climate Action Plan 2050 calls for efforts to develop a culture of participation in climate action, and thereby to initiate and reinforce relevant social processes for learning and innovation. In this context, the plan is oriented especially to the following UN Sustainable Development Goals: Gender Equality (SDG 5), Reduced Inequalities (SDG10) and Peace, Justice and Strong Institutions (Governance; SDG 16). In addition to opportunities for public participation, citizens need specific, easily accessible options for getting involved themselves – for example, at the district and neighbourhood levels – since such options reinforce awareness about the need for climate protection and foster commitment to climate action.

In this area, municipalities, the Länder (German states) and companies and organisations are all called on to offer information and education services – if need be, with financial support from the federal government – and to acknowledge and thereby reinforce the commitment that is already being shown.

On an ongoing basis, the federal government carries out public relations measures (including information campaigns) aimed at raising awareness about issues pertaining to climate action, Germany’s energy system transformation (Energiewende) and the need to use resources efficiently.

9.3.1 The “Climate Action 2050” (“Klimaschutz 2050”) information campaign for the Climate Action Programme 2030

In connection with its Climate Action Programme 2030, the federal government has decided to carry out an information campaign has entitled “Climate Action 2050” (“Klimaschutz 2050”). The aim of the campaign is to foster public acceptance of the need for additional climate-protection measures. The campaign seeks to motivate citizens to think about what they can do, personally, to contribute to climate protection. The federal government plans to support citizens’ openness to climate action by providing an Internet portal on which citizens and companies alike can inform themselves about options for useful action. In 2020 and 2021, the campaign’s central information portal was provided at www.unser-klimaschutz.de.

The immediate climate action programme for which coordination between different parts of the federal government is currently underway will also include measures for informing the general public or specific target groups. Consultations regarding its structure and design are currently still taking place.

9.3.2 Campaigns for climate action

Online climate action campaign: This campaign, which was launched in 2020 and is being funded by the Federal Ministry for Economic Affairs and Climate Action (BMWK), is

informing the public about the impacts of climate change, and encouraging and advising target groups regarding ways to permanently reduce their carbon footprints and thereby contribute to the attainment of Germany's climate protection goals. Its innovative, database-supported and personalised online-advising services are complemented by services such as public relations, information for users, and campaigns/efforts for specific groups, such as "energy champ" competitions (Energiesparmeister-Wettbewerb), brochures on available funding and publicity about heating mirrors. Its advising services are updated daily and adapted to new conditions and frameworks as necessary. Between in July 2020, when the campaign began, and August 2022, the campaign has provided some 1.4 million consultations. Through August 2022, the campaign had reached a total of 8.6 million visitors on all of its Internet presences.

Energy campaign for the hospitality, wholesale and foreign trade sectors: This BMWK-funded project is aimed at accelerating energy-efficiency progress, and thereby at contributing to CO_2-emissions reductions, in the German hospitality, wholesale and foreign trade sectors. To this end, the project provides useful information about ways to increase energy efficiency. It especially emphasises transfers of know-how between the two associations involved. In addition, it provides clear incentives for implementation of measures – for example, via clear presentations of best-practice examples and via use of online tools. The project applies a holistic approach that makes use of the broad reach of modern, interactive information campaigns, includes high-quality individual advising on location and generates additional competitive advantages for committed companies.

Climate action campaign for the food industry: "PlusPlus Prinziple" ("PlusPlus-Prinzip") is a BMWK-funded information campaign being carried out by the German food industry on energy efficiency, renewable energies and climate action. It promotes immediate-action measures for energy saving in production (process heat, process cooling, etc.); fast approval and implementation of investments; renewable-energy concepts for companies' locations; and giving energy efficiency and climate protection high priority in management systems.

The "Jugend forscht" youth science-contest organisation – special prize in the area of "Energy system transformation and Climate action": The "Jugend forscht" youth science-contest organisation is ideally suited to the tasks of motivating people to become involved in climate action and of raising public awareness. The special prize in the area of "Energy system transformation and Climate action," and the Jugend forscht "PerspektivForen" discussion events, provide special incentives for schools (pupils, parents, teachers) to explore climate action / climate change topics, acquire new knowledge, develop ideas and carry out projects.

9.3.3 Campaigns for the Energiewende

In general, the Energiewende, Germany's energy system transformation, is perceived very positively by the German public, and it is widely supported. At the same time, infrastructure projects needed for the Energiewende, such as expansions of electricity transmission grids, sometimes meet with considerable local resistance. Since 2015, the BMWK has been funding the initiative "Citizens' dialog on the electricity grid" ("Bürgerdialog Stromnetz"), with the aims of fostering public acceptance of transmission-grid expansions and raising public awareness about this issue. Since 2020, this effort is being carried out in the framework of a follow-on project, with a new contracting entity. The initiative is designed to promote broad-based public dialog about the electricity-grid expansion that is needed if the Energiewende is to succeed.

The initiative provides basic information about the grid expansion, about the connections between the grid expansion and the Energiewende and about the options for public participation. Also, it serves as a platform for dialog, by conducting various kinds of public and stakeholder events and discussions, directly in regions affected by grid expansions. Its “Dialogmobil” public relations vehicle travels directly to relevant sites. The initiative’s services are rounded out by a website, with an online citizens’ office.

Other communications about the Energiewende energy system transformation, in recent years, have focussed on topics such as the positive results obtained in implementing the Energiewende so far (October – December 2015) and, especially, the progress made in expansion of renewable energies, and the economic impetus provided by the Energiewende. These aspects were emphasised in the special publication “Die Energiewende: unsere Erfolgsgeschichte” (“The Energiewende: our success story”), which in early 2017 appeared nationwide in leading pan-regional media. It features relevant facts and figures, context and background, and emerging trends.

In 2021, funding in the buildings sector was restructured: The various programmes underway were consolidated within a major funding programme, KfW/BAFA programmes to financially support ambitious energy standards for new buildings and renovations (Bundesförderung für effiziente Gebäude – BEG). This programme will now make it possible to fund measures for energy efficiency and renewable energies under one umbrella. In addition to being featured in flyers and fact sheets, the BEG programme is being publicised primarily via the campaign website energiewechsel.de.

In June 2022, the Federal Ministry for Economic Affairs and Climate Action (BMWK) launched the information and activation campaign “80 million working together for energy change” (“80 Millionen gemeinsam für Energiewechsel”), which is scheduled to run until the end of 2025. Aimed at end consumers, companies, business people, associations, municipalities and non-profits, and covering topics such as energy-saving, increasing energy efficiency and expanding use of renewable energies, it seeks to raise awareness, encourage people to get involved and to provide a broad fund of information. One of the campaign’s central messages is that the Energiewende energy system transformation is a joint project of the entire society. The background to this is that the Energiewende plays a decisive role in our ability to achieve a climate-neutral, economically successful and independent energy future. This year, in light of the current energy crisis, the priority is on energy saving. The campaign provides general information for consumers, specific tips on energy efficiency measures and information about the federal government's available support.

The aim of the “Energy of the future” (“Energie der Zukunft”) monitoring process is to review implementation of measures for the Energiewende and for the relevant energy concept (including its goals), with a view to achieving a reliable, cost-effective and environmentally friendly energy system – and to taking corrective action as necessary. The federal government publishes the results of the monitoring process annually, in a monitoring report. Every three years, a progress report also appears, in addition to the regular monitoring report. It offers a more-comprehensive perspective on the Energiewende, facilitates in-depth analyses over longer periods of time and looks ahead to the future. The reports are provided to both chambers of the German parliament – the Bundestag and the Bundesrat.

A commission of independent energy experts supports the monitoring process. The commission of experts responds, on a scientific basis, to the federal government's monitoring and progress reports. The monitoring process contributes to transparency in connection with the Energiewende – and, thus, helps foster acceptance for it.

9.3.4 Bringing Education for Sustainable Development (ESD) to the society at large

In the framework of German implementation of the UNESCO ESD for 2030 programme, the Federal Ministry of Education and Research (BMBF) is providing funding to support national, international and regional dialog, and to enhance the profile of ESD within the German UNESCO Commission (DUK). This is taking place via, inter alia, awarding of ESD National Awards. Since 2016, these have been awarded (now, three times annually) for high-quality educational services, and for effective, future-oriented commitment with benefits for sustainable development. In connection with implementation of UNESCO's new ESD for 2030 programme, a new endowed ESD prize has been introduced. In the prize categories "Places of ESD," "ESD Multipliers," "ESD Educational Landscapes" and "Newcomers," it honours successful, structurally holistic examples of ESD implementation and publicises them nationally and internationally.

For the many actors and stakeholders involved in the practical aspects of ESD, the BMBF-funded Internet portal www.bne-portal.de is an important source of information about education for sustainable development. It highlights key players in ESD; presents an overview of outstanding ESD learning sites, municipalities and networks; and provides an overview of current news, events and publications. The portal also offers educational materials for ESD. Originally, the portal was operated by the German UNESCO Commission (DUK). In 2020, the BMBF assumed responsibility for the portal.

The various bodies active in the ESD sector include ESD partner networks that facilitate interaction between educators and stakeholders from all areas of society. The networks provide impetus for local implementation of ESD. In doing so, the promote acceptance for ESD and the visibility of ESD, organise events and prepare good-practice examples of ESD. They also focus on sub-areas of ESD, and they work with the various ESD forums. The partner networks are organised into the following topic areas: "Early childhood education", "vocational training and further training", "higher education institutions", "the media", "biological diversity", "the world of extracurricular education", "cultural education and cultural policy", "economics and consumption", and "municipalities and ESD". The partners' forum, which brings together all of the partner networks, organises "open days," a regionally oriented event format designed to attract additional attention and develop new target groups for ESD. It also is charged with supporting the establishment of new partner networks – and thereby placing ESD on a broader basis. In terms of content, the regularly held "open days" are oriented to the focus topics of the ESD National Platform (NP ESD) and the UNESCO "BNE 2030" programme. They help partner-network members from the various relevant regions become involved, and they facilitate use of municipal infrastructure and resources.

9.4 Vocational training

Ecological and technological change is creating many new requirements pertaining to the curricula and the teaching and training staffs of the Germany's proven dual vocational and training system. The federal government and the social partners (employers' and employees' representatives) are continuing their joint efforts aimed at reinforcing and enhancing the attractiveness, quality and performance of the dual vocational and training system, with a view to ensuring that the dual system continues to be successful, and that trainees continue to receive the qualifications they need for the workplace of tomorrow. The focuses of these efforts include ongoing modernisation of training/education regulations, oriented especially to competencies for managing ecological and digital transformation. In this context,

the new standard training elements provide minimum standards for all dual-system training, including in areas such as sustainability, environmental protection and the digitalised workplace. In addition, close contacts between the federal government, the Länder, the social partners (employers' and employees' representatives) and scientific experts are being continued and reinforced, with a view to identifying the competencies and qualifications needed for the vocational training system.

9.4.1 The “Vocational Training for Sustainable Development” (“Berufsbildung für nachhaltige Entwicklung”) (BBNE) funding programmes

The aim of structurally integrating education for sustainable development within vocational training is also supported by funding measures of the Federal Ministry of Education and Research (BMBF) that impart sustainability-oriented competencies within vocational training. To enable transfer of BBNE further training concepts that have been developed and tested, the Federal Institute for Vocational Training (BIBB), with funding from the BMBF, is currently carrying out model tests on the dissemination and establishment of successful, sustainability-oriented approaches for further training of vocational training teaching staff. Via an additional, ESF-co-financed funding programme, such training measures are now to be applied throughout Germany.

These holistic funding approaches of the BMBF are contributing to implementation of the Federal Government's Sustainability Strategy (Quality Education), which is based on the UN Agenda 2030 for Sustainable Development.

In the area of vocational training, the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) has consolidated its efforts within the funding programme “Vocational Training for Sustainable Development” ("Berufsbildung für nachhaltige Entwicklung.” In the framework of the current European Social Fund (ESF) funding period, 2014-2020, the BBNE programme is also imparting “key green competencies for climate-friendly, resource-saving action in the workplace” (“grüne Schlüsselkompetenzen zu klima- und ressourcenschonendem Handeln im Beruf”).

The ESF programme BBNE is the first federal programme, in the more than 50 years in which the ESF has been in existence, to have an explicit emphasis on environmental and climate protection. In the framework of the second funding round, which began in 2018, four of a total of 13 funded projects are oriented to concrete climate action measures. In practically oriented training courses, trainees, and educational staff involved in their training, learn how the interfaces between the various trades can be further improved. Optimal management of inter-trade cooperation, in combination with a systems approach to buildings and structures, is conducive to high-quality renovation and construction oriented to energy efficiency.

The four projects oriented to climate action measures include:

- Goal 13 – Construction as climate action[217],
- GESA – Gewerkeübergreifende Qualifizierung im Rahmen energetischer Gebäudesanierung (Cross-cutting training in the framework of energy-related modernisation of buildings)[218],

[217] https://ziel13.nznb.de/
[218] https://bbne-mutzenbecher.blogs.uni-hamburg.de/

- Smart builder – Ausbildung für Kommunikation und Kooperation am Bau (training for communication and cooperation at building sites)[219],
- GREENCRAFT – Grünes Handwerk Thüringen (Green trades in Thuringia)[220].

9.4.2 Education initiative for promoting energy efficiency in buildings I (Bildungsinitiative für Gebäudeeffizienz I) – Build Up Skills

The project “BUILD UP Skills – QUALITRAIN” supports vocational training and further training of persons employed in the construction industry, as well as the establishment of a national training platform with European Union funding.

9.4.3 Development programme on heat pumps (Aufbauprogramm Wärmepumpe)

On 13 July 2022, the Federal Ministry for Economic Affairs and Climate Action (BMWK) and the Federal Ministry for Housing, Urban Development and Building (BMWSB) jointly presented an immediate-action programme for the buildings sector pursuant to Section 8 (1) Federal Climate Change Act. The programme was necessary because the buildings sector exceeded its annual emission budget in 2021. Its proposed measures include the “Development programme on heat pumps” (“Aufbauprogramm Wärmepumpe”). Thanks to their high efficiency and potential to achieve GHG neutrality, heat pumps are a key technology for the heat sector. Plans call for the development programme to comprise short training courses on the planning, installation and proper adjustment of heat pumps.

9.5 Information and advising services

9.5.1 International communication about the Energiewende, Germany’s energy system transformation

The project International communication about the Energiewende, Germany’s energy system transformation (internationale Energiewende-Kommunikation) has been carried out by the German Energy Agency (dena), on behalf of the Federal Ministry for Economic Affairs and Climate Action (BMWK), since 2020. The project aim is to publicise – both in Germany and worldwide – measures, successes and challenges related to the Energiewende, and to do so in a manner that supports energy-system transformation, a key future issue. At the same time, it is promoting concrete solutions for climate-neutral economies, and best practices from Germany, to an international audience in the areas of policy, industry, civil society and science; explaining central decisions made relative to the Energiewende and climate action; and promoting interaction between stakeholders. The project’s measures and instruments are being applied in the context of the federal government's bilateral energy partnerships and dialogs, as well as of other bilalateral and multilateral cooperation and networks. The project’s central focuses include jointly promoting dialog between partners, reciprocal knowledge transfer and exchanges of experience relative to the global energy system transformation; and supporting efforts toward international climate protection goals and toward global decarbonisation.

[219] https://www.rhein-main-campus.de/de/kurstipps-und-news/smart-builder-bildung-am-bau
[220] https://www.grüneshandwerk.de

9.5.2 Export initiative on energy

The federal government's export initiative on energy (Exportinitiative Energie) supports German providers of climate-friendly energy solutions in presenting themselves successfully in international markets. Promotion of global dissemination of climate-friendly energy technologies actively contributes to global climate protection. In addition to maintaining a website, at www.german-energy-solutions.de, the Initiative publishes brochures and newsletters and holds events.

9.5.3 SME Initiative Energy Transition and Climate Protection (Mittelstandsinitiative Energiewende und Klimaschutz)

The federal government founded the SME Initiative Energy Transition and Climate Protection in cooperation with the German Chamber of Commerce and Industry (DIHK) and the German Confederation of Skilled Crafts (ZDH). It supports German SMEs in activities related to the Energiewende energy system transformation. Its aim is to help companies tap into potential for saving energy and to improve their overall energy efficiency. Since 2012, the SME Initiative has been providing information, training and opportunities for discussion. It provides useful support and helps companies find useful contacts in their own locations. As a result of its success, the Initiative continued its work in the years 2016 – 2018 and expanded its scope to include additional companies, associations and energy consultants. The federal government plans to expand its efforts to promote dialog between policymakers and SMEs; to optimise its information and advising services; and to promote exchanges of experience for many years to come.

9.5.4 Renewable energies

The federal government's measures in the area of renewable energies are presented to the public on the website www.erneuerbare-energien.de, which is continuously updated. The website is complemented by a diverse range of publications, including publications focussed on renewable energies, and the annual publication “Renewable Energies in Figures” (“Erneuerbare Energien in Zahlen”) (in German and English), which provides an extensive range of specialised information about the development of renewable energies in Germany. In the same framework, information is provided about the GHG emissions reductions achieved via use of renewable energies. The satellite website available at www.erneuerbare-energien.de also offers services for use of graphics/tables in presentations.

9.5.5 Information services of the German Energy Agency (dena)

The German Energy Agency (dena) is a center of excellence for Energiewende and climate action applications. dena studies the challenges involved in enabling society to become climate-neutral, and it supports the federal government’s efforts towards its energy-policy and climate-policy goals. Since 2000, when it was founded, dena has developed relevant solutions and implemented them in practical applications, and it has brought stakeholders in the areas of policy, industry, science and society (including virtually all segments) together – at both the national and international levels. dena is a project corporation and a public-sector, federally owned company. Its shareholders are the Federal Republic of Germany and the KfW Bank Group.

A. Annex – Fifth Biennial Report under the United Nations Framework Convention on Climate Change, 2022

The fifth Biennial Report is being submitted simultaneously with the eighth National Communication, and it is integrated within the National Communication. In this Annex, reference is made to the relevant chapters of the above report, in keeping with the structure proposed in the UNFCCC Guidelines for Biennial Reports. The following section provides additional clarification for passages for which clarification is needed.

A 1. Information on GHG emissions and trends, and on GHG inventories, including information on the National System of Emissions Inventories

An overview of the GHG emissions of the years 1990 through 2020, and of the most important relevant trends, is provided in Chapter 3.3 above. The emissions data given in the 8th National Communication, and in the 5th Biennial Report, are consistent with the current UNFCCC reporting for the year 2022.

The National System for inventory preparation is described in Chapter 3.4. That description also covers institutional changes. No additional institutional changes have taken place since the last National Communication. A description of the National Registries is provided in Chapter 3.5 of the 8th National Communication.

A 2. Description of the national quantified reduction target for greenhouse gases

A 2.1. Joint goal of the European Union for 2020

Under the UNFCCC, the EU and its Member States committed to achieving a joint quantified economy-wide greenhouse gas emission reduction target of 20 per cent below the 1990 level by 2020 (“the Cancun pledge”). It is therefore a joint pledge with no separate targets for Member States under the Convention. The UK remains part of the joint EU 2020 target together with the 27 EU Member States.

Table 17: Description of the European Union's quantified emissions reduction target

Parameter	Description
Base year	1990
Target year	2020
Emissions reduction target	-20 %
The target covers the greenhouse gases…	CO_2, CH_4, N_2O, HFCs, PFC, SF_6
GWP (Global warming potential)	AR4
Sectors	All sources and sectors pursuant to IPCC (Intergovernmental Panel on Climate Change), international aviation is partly included
LULUCF	Not included
Crediting of flexible mechanisms	Possible, under certain conditions, under the ESD and the ETS (Emissions Trading System)

The EU has jointly committed to its UNFCCC target and implemented it internally through EU legislation in the 2020 EU Climate and Energy Package. In this package, the EU introduced a clear approach to achieving the 20% reduction in total GHG emissions from 1990 levels, by dividing the effort between the sectors covered by the EU Emissions Trading System (EU ETS) and the sectors under the Effort Sharing Decision (ESD). Binding national targets were set for Member States under the Effort Sharing Decision. The achievement of EU internal compliance under the 2020 Climate and Energy Package including the national targets under the ESD is not subject to the UNFCCC assessment of the EU's joint commitment under the Convention.

A 2.2. National Targets

The national climate goals are described in Chapter 4.1 above: In its Federal Climate Change Act, which was adopted in 2019 and amended in 2021, Germany has committed itself to achieving net climate neutrality by 2045. The Act also calls for emissions reductions of at least 65 % by 2030, and of at least 88 % by year 2040, with respect to 1990 levels.

Prior to the Climate Change Act, the goals defined in the Climate Action Plan 2050 applied. As a short-term reduction goal, the federal government had aimed to reduce GHG emissions by 40 %, with respect to 1990, by 2020.

A 3. Progress toward the national emissions reduction target

A 3.1. Reduction measures, and their impacts

Chapter 4.5 above provides a detailed description of the policies and measures, and their reduction effects. Since projections for 2020 were not available for all measures, projections

for 2021 have been given where possible. An overview of the policies and measures has been included as Table 8 at the end of Chapter 4.5. It is also being included as CRF Table 3.

The Climate Change Act provides for an annual monitoring and correction mechanism designed to ensure that Germany achieves its climate goals. That mechanism is described in Chapter 4.1.1.

A 3.2. Assessment of emissions reduction, crediting of market-based instruments and LULUCF

Joint goal of the European Union for 2020

The EU has substantially overachieved its reduction target under the Convention, which means that also its Member States and the United Kingdom have fulfilled their emission reduction obligations. As stated in the 2022 EU GHG inventory submission to the UNFCCC, the total GHG emissions, excluding LULUCF and including international aviation, decreased by 34% in the EU-27 + UK compared to the base year 1990 or 1.94 billion tons of CO2e (carbon dioxide equivalent).

Reduction targets pursuant to Effort Sharing Decision

Via Effort Sharing Decision, each EU Member State is assigned an annual emissions budget, its Annual Emission Allowance (AEA). Whether a state has exceeded its AEA or stayed below it is determined by calculating ESD emissions. For calculation of ESD emissions, emissions covered by the EU ETS, emissions from national aviation and F-gas emissions are deducted from the total emissions (not including LULUCF) given in the greenhouse-gas inventory.

Germany has reached its targets pursuant to the Effort Sharing Decision (ESD). To offset its cumulative balance for 2020 (cf. Table 18), Germany used emission allowances that it had acquired from other EU Member States.

Year	AEA:	ESD emissions:	Balance (cumulative as of 2013)
2013	472,527,651	460,204,908	12,322,743
2014	465,830,461	436,790,185	41,363,019
2015	459,133,271	444,080,615	56,415,675
2016	452,436,081	454,157,411	54,694,345
2017	432,348,857	466,857,281	20,185,921
2018	425,202,158	434,047,773	11,340,306
2019	418,055,459	444,262,722	-14,866,957
2020	410,908,761	407,410,808	-11,369,004

Table 18: ESD emissions

Use of international market mechanisms in the EU ETS

The EU ETS does not define national targets for the individual Member States; instead, it specifies an EU-wide upper boundary. As a state, Germany has not made use of any international market mechanisms in the EU ETS. Within Germany, operators of installations subject to emissions-trading requirements, and operators of aircraft, have made use of certificates from international market mechanisms, however. In Phase 3 of EU emissions trading, which ran from 2013 through 2020, a total of 85,300,761 CER and 61,248,670 ERU were used by operators of installations subject to emissions-trading requirements and by operators of aircraft. Those instruments were not used toward fulfilment of the EU's common reduction target, however.

Use of CER and ERU over the years breaks down as follows:

Year	Use of CER:	Use of ERU:
2013	8,197,820	20,366,603
2014	48,512,212	40,882,067
2015	3,386,621	0
2016	3,147,879	0
2017	2,312,486	0
2018	5,327,080	0
2019	9,175,727	0
2020	5,240,936	0

Table 19: Use of CER and ERU by operators of installations subject to emissions-trading requirements and by aircraft operators

Since the deadline for the previous year is April 30 of the following year, exchange transactions were combined from May 1 to April 30 of the following year. For example, exchange transactions from 01/05/2016 to 30/04/2017 were assigned to the year 2016.

Achievement of the national target for 2020

The federal government's target of reducing GHG emissions in Germany by at least 40 % by 2020, with respect to 1990 levels, was achieved. GHG emissions decreased from about 1,250 Mt CO2e in 1990 to about 728 Mt CO2e in 2020.

The achievement of the national GHG-reduction targets was measured on the basis of the country's official National Inventory data. The national targets, therefore, include the emissions of all greenhouse gases covered by the Kyoto Protocol. They refer to domestic emissions of all sectors, and they do not include credits from Land Use, Land Use Change and Forestry (LULUCF) or credits from flexible mechanisms such as the Clean Development Mechanism (CDM) and Joint Implementation (JI).

A 4. Projections

A 4.1. Projections for 2020 and 2030

Information about the projections is provided in Chapter 5 – “Projections and overall impacts of policies and measures to reduce greenhouse gases” above and is presented in CRF Table 3. The reduction effects of the underlying policies and measures are described in Chapter 4.5, and they are also included in CRF Table 3.

A 4.2. Changes in the projections

Information about improvements and changes, with respect to the last Biennial Report, is provided in the second half of Chapter 5.2.1 – “Methodological approach for the emissions projections, and changes since the last Biennial Report.”

A 5. Financial and technical support for, and capacity-building in, developing countries

This information is provided in the report’s Chapter 6 “Financial Support and Technology Cooperation.”