Federal Ministry
for Economic Affairs
and Climate Action

Climate Action in Figures

Germany's current emission trends and climate action measures
2022 edition

bmwk.de

Publication details

Publisher
Federal Ministry for Economic Affairs and Climate Action (BMWK)
Public Relations
11019 Berlin
www.bmwk.de

Date
July 2022

This publication is available for download only.

Design
www.digitale-gestaltung.de, Holger Ebeling, Berlin

Picture credits
Cover: Adobe Stock / anatoliy_gleb
Page 8: Adobe Stock / ValentinValkov · Page 14: Press and Information Office of the Federal Government / Sandra Steins
Page 22: Adobe Stock / Uwe · Page 48: Adobe Stock / ATKWORK888

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Foreword

Dear readers,

The crux of climate change is that it is gradually creeping into all our lives. Rising temperatures are causing more incidents of drought and heavy rainfall. We are increasingly able to observe this physical correlation in Germany too. Soil has dried out on a large scale; the harvest of grain maize is catastrophically low in many regions. Some rivers are recording historically low water levels, thereby severely restricting shipping. At the same time, heavy rainfall is on the rise. The fatal and disastrous flooding in the Ahr valley was just a year ago. What counted as extreme weather events in my childhood are increasingly becoming the new normal. Future extremes will far exceed what we know from the old records kept by our villages and cities.

The report before you is clear: Germany is still making an above-average contribution to climate change. Last year, about eight tonnes of CO_2 were released into the atmosphere per capita. That amounts to two to three more tonnes than the global average. The main cause is the demand for fossil fuels such as coal, oil and gas in electricity generation, industry, transportation and heating.

I have set out to change this. The use of fossil fuels is not only driving climate change and damaging our health through air pollution; it also has no economic future. Their use is often inefficient – the efficiency of a car's internal combustion engine only amounts to around 30% in actual use – and they constantly have to be replenished, which results in costly dependencies. We are currently being reminded of this in an especially painful way.

Fortunately, there are alternatives, notably renewable energy, electrification, energy efficiency and reduced consumption, with which we are actively pressing ahead. This summer we created the conditions to significantly speed up and expand the use of renewables via our package of immediate energy action. By 2030, we want 80% of electricity to be generated from renewable energy.

Overall, pursuant to the provisions of the Federal Climate Change Act, greenhouse gas emissions have to be brought down from about 762 million tonnes of CO_2 equivalents in 2021 to about 435 million tonnes by 2030. Net greenhouse gas neutrality is to be achieved by 2045. We will then only be allowed to release as much greenhouse gas into the atmosphere as can be absorbed in the same time period, e.g. by forests.

It is now vital that we adjust our lives and economic activity towards this goal. This requires a multitude of ideas, clever innovations, openness and the willingness to change. I am confident we can work together and thus considerably mitigate climate change.

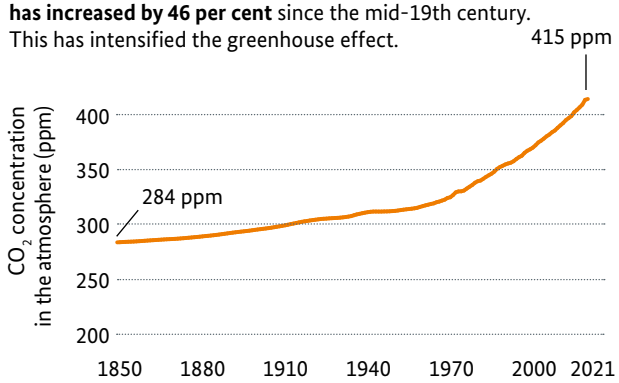
Yours sincerely,

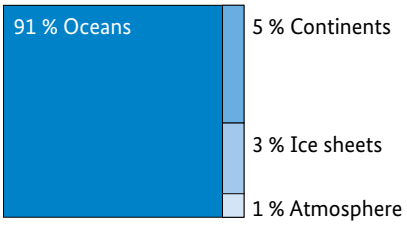
Dr. Robert Habeck
Federal Minister for Economic Affairs and Climate Action

Climate Action in Figures – compact

Causes of climate change

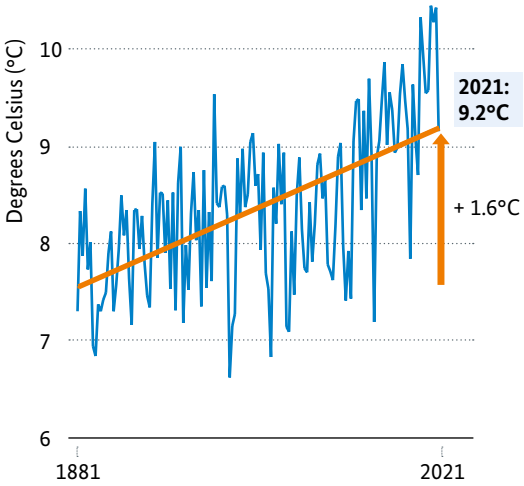
The concentration of **carbon dioxide in the atmosphere has increased by 46 per cent** since the mid-19th century. This has intensified the greenhouse effect.





As a result, less energy is returned to space than the amount of radiant energy absorbed. Most of the excess energy **warms the oceans** (91 per cent).

Climate change impacts in Germany



Since 1881, the long-term temperature trend in Germany has already increased **by 1.6°C**. The ten-year period 2011 to 2020 was around 2°C warmer on average than the reference period 1881 to 1910.

Climate change impacts can already be observed in Germany today and will increase significantly in the coming decades. This includes extreme weather events such as heavy precipitation and heat waves.

Heat
Number of hot days (≥ 30°C)
+187 % since 1951*

Heavy rainfall
Number of days ≥ 20 mm
+5 % since 1951*

Sea level rise
Over the past hundred years, sea levels in Cuxhaven have risen by an average of 18 cm

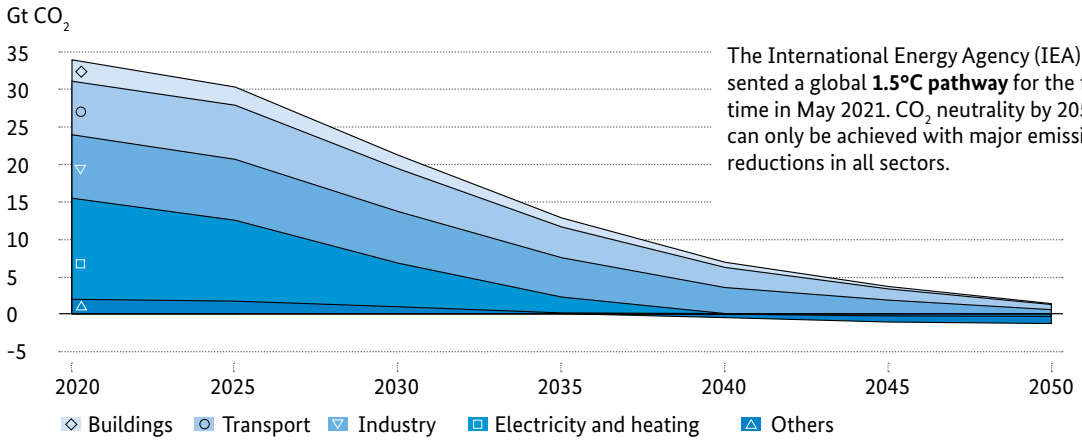
Snowy days
Number of days with 24 h exclusively snowfall
-48 % since 1951*

Cold
Number of ice days (< 0°C)
-50 % since 1951

Sunshine duration
-11 % 1951 to 1980
+16 % since 1981
+9 %*

*Ratio of the linear trend from 1951 (or respectively 1881, 1981) to 2021 to the mean value of the reference period from 1961 to 1990

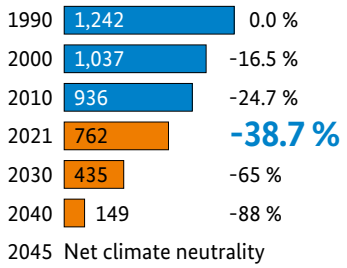
International climate action



The International Energy Agency (IEA) presented a global **1.5°C pathway** for the first time in May 2021. CO_2 neutrality by 2050 can only be achieved with major emission reductions in all sectors.

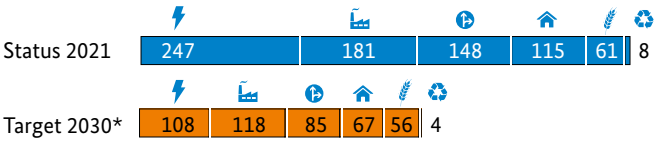
Emission trends and targets in Germany

Reduction in German greenhouse gas emissions compared to 1990:



Million tonnes CO_2 equivalent

German greenhouse gas emissions by sector:

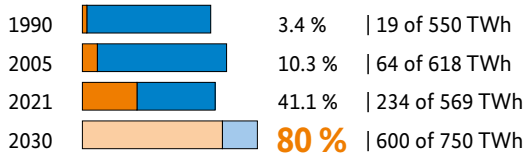


Energy · Industry · Transport · Buildings · Agriculture · Waste management and others

*Maximum permitted annual emission levels according to the Federal Climate Change Act

Towards a climate-neutral economy

Share of renewable energies in electricity consumption



In 2021, renewables accounted for 41.1 % of electricity consumption. With the completion of the coal phase-out, the goal is to generate almost all of Germany's electricity from renewable energies.

The sources for the illustrations can be found in the corresponding sections.

1. Climate change challenges

Summary

Causes and global consequences: Since industrialisation, human activities have been increasingly releasing greenhouse gases. These accumulate in the atmosphere and intensify the greenhouse effect. The average global temperature is rising. Carbon dioxide (CO_2) accounts for the majority of the additional greenhouse effect caused by humans. In 2021, the CO_2 concentration in the atmosphere was 415 parts per million (ppm) and had thus risen by 46 per cent since the pre-industrial era. This increase is the main driver of climate change. Most of the excess heat is absorbed by the oceans. This, along with the loss of glaciers and ice sheets, is causing the global average sea level to rise.

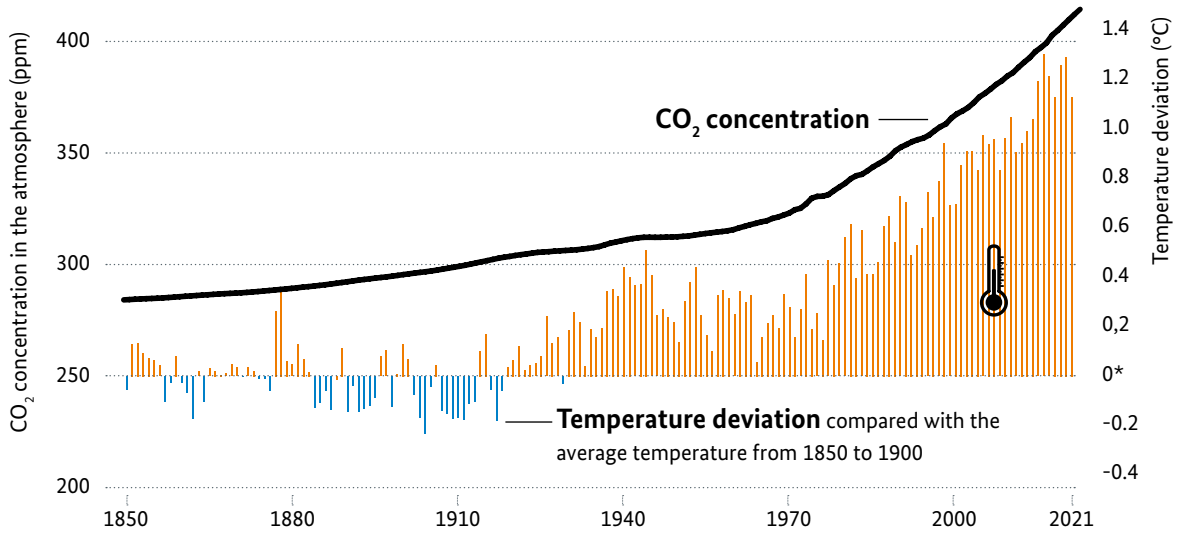
Consequences and economic costs in Germany: The pace of temperature increase has accelerated significantly in Germany, as elsewhere. Nine of the ten warmest years since 1881 have occurred after the year 2000. Furthermore, reduced precipitation in 2018, 2019 and 2020 resulted in a drought that was unprecedented in the past 250 years. At the same time, heavy rainfall events have become more likely. Flood events such as those in the regions around the Ahr and Erft rivers in 2021 cost human lives and have caused record financial losses. These damages demonstrate the risks that extreme weather can pose, especially if these events increase in intensity and frequency in the future.

1.1 Causes and global consequences of climate change

It is clear that human influence has warmed the climate.[1] Dramatic climate changes in recent decades are not explained by natural climate variability. The rise in global surface temperature is due to the greenhouse effect, which is amplified by anthropogenic emissions of greenhouse gases and their accumulation in the atmosphere. These emissions are produced, for example, by the burning of coal, crude oil and natural gas, or as a result of deforestation. Particularly since the middle of the 19th century, the concentration of greenhouse gases in the atmosphere has been steadily increasing, especially CO_2. The CO_2 concentration today has not been this high for probably two million years.[2] In 2021, it was 415 ppm and had thus increased by 46 per cent since the pre-industrial era.[3] The concentrations of other climate-relevant greenhouse gases, such as methane (CH_4) and nitrous oxide (N_2O), have also risen significantly. Figure 01 illustrates the relationship between the rising concentration of carbon dioxide and an increase in global surface temperature. The implication is that the temperature will continue to rise as long as more carbon dioxide continues to be emitted than is sequestered by sinks such as forests. In 2021, the average global temperature was about 1.1°C above the pre-industrial level (1850 to 1900).[4]

These climate changes are unprecedented in their scale and speed. Because of the greenhouse effect, the earth experiences a radiative imbalance. This means that less energy is emitted from the earth into space than is supplied. Small amounts of this excess energy heat the atmosphere and the continents, turn water into vapour and melt ice. Most of the energy – around 91 per cent – warms the oceans (see Figure 02). Consequently, the ocean acts as a buffer, absorbing most of the excess heat and slowing down the warming of the atmosphere.[5] The latest and sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) analyses the current state of the global climate and highlights the extent of recent changes in the climate system as a whole. Along with a rapid increase in air temperature over the last 50 years, the surface of the oceans has warmed by 0.6°C since 1980. The warming oceans expand, and this accounts for about half of the global sea level rise so far. Increasingly, ice loss from glaciers and ice sheets is also contributing to sea level rise. For example, the rate of ice sheet loss increased fourfold between 2010 and 2019.[6] Since 1901, the aver-

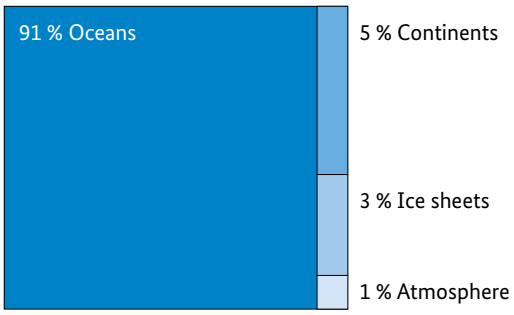
Figure 01: **Atmospheric carbon dioxide concentration and change in global surface temperature since 1850**



*The temperature zero line shows the average temperature from 1850 to 1900.

Sources: Climate College (2016), Met Office (2022), NOAA (2022)

Figure 02: **Where does the energy from global warming go?**



Source: IPCC (2021a)

age global sea level has risen by 20 centimetres, and by around 5 centimetres since 2010 alone.[7]

As well as heat, the ocean also absorbs part of the CO_2 from the atmosphere, reducing the greenhouse effect. However, a higher CO_2 concentration in the water lowers its pH value, making the oceans more acidic. In addition to ocean acidification, climate change will also increase the stratification of the upper ocean and the ocean deoxygenation in the 21st century, with the rates of these increases depending on future emissions.

With each further increase in global warming, climate changes are becoming more severe. Recent years have brought continued reports of new warming records. Just recently, in the spring of 2022, the coldest place on the planet in Antarctica experienced a series of temperatures never seen before. Temperatures were up to 40°C higher than the long-term average.[8] India and Pakistan endured an unusually extreme heat wave lasting weeks in the early part of 2022. The warming of the earth's surface, atmosphere and oceans is already affecting many weather and climate extremes in all regions of the world. According to the IPCC's climate models, global surface temperature will continue to rise until the middle of the century in all emissions scenarios considered. Global warming of 1.5°C could be exceeded even before 2030 if emissions are not drastically cut in the coming years.[9] Each additional 0.5°C of global warming will lead to a significant increase in the intensity and frequency of heat waves and heavy precipitation. Agricultural and environmental droughts will increase in some regions. An increase in the proportion of violent tropical cyclones and a further loss of Arctic sea-ice, as well as snow cover and permafrost, are also directly related to the rising temperature.[10]

Climate change is affecting nature and people worldwide. The latest IPCC report points out that increasing heat waves, droughts and floods are already exceeding the tolerance threshold of plants and animals, leading to mass extinctions of species such as trees and corals. Climate, ecosystems, biodiversity and human societies are mutually dependent. It is particularly problematic that weather extremes occur simultaneously, resulting in cascading impacts that are increasingly difficult to manage. This is particularly true in Africa, Asia, Central and South America, small islands and the Arctic. In these regions, millions of people are already facing acute food and water insecurity.[11]

According to the IPCC, limiting global warming to below 1.5°C is immensely important, because even a short-term overshoot could have severe and irreversible consequences.[12] However, this means that global greenhouse gas emissions would have to peak by 2025 at the latest and be cut by 43 per cent by 2030. Even then, it is almost certain that this temperature threshold will be exceeded for a time.[13] Therefore, the next few years are critical for the implementation of climate action measures.

With accelerated and ambitious action, emissions can be halved by 2030. The IPCC report shows that options to reduce emissions exist in all sectors and must be used. A fundamental change is needed in the energy sector. This includes a significant reduction in fossil

+1.1°C

In 2021, the global average temperature was about 1.1°C above pre-industrial levels (1850 to 1900).

> *"Our planet is changing before our eyes — from the ocean depths to mountain tops; from melting glaciers to relentless extreme weather events. Sea-level rise is double the rate it was 30 years ago. Oceans are hotter than ever — and getting warmer faster. Parts of the Amazon Rainforest now emit more carbon than they absorb."*
> *António Guterres, United Nations Secretary-General, COP26 in Glasgow, November 2021*

fuel consumption, widespread electrification, improvements in energy efficiency and the use of alternative fuels (such as hydrogen). In this regard, cities offer considerable potential for cutting emissions and increasing resource efficiency at the systemic level, e.g. by transitioning urban infrastructure to net zero emissions via low-emission development paths. If this reduces emissions throughout the goods supply chain, including outside of urban areas, then positive cascade effects will be triggered in other sectors. Cutting emissions in industry requires a more efficient use of materials, re-use and recycling of products, and minimisation of waste, as well as greater energy efficiency and switching to climate-friendly energy sources. Some industries must first develop new production processes to meet these goals.[14]

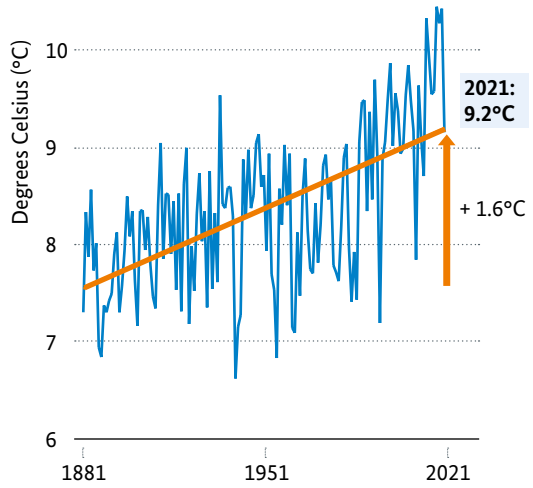
In addition, action is required to adapt to the impacts of climate change. To prevent the loss of human life, biodiversity and infrastructure, strong measures to adapt to warming must be taken worldwide, in addition to halting anthropogenic (human-caused) greenhouse gas emissions. These include artificial irrigation of fields, planting forests and an expansion of green spaces in cities, as well as public transport. Protecting and strengthening ecosystems is also of central importance. In order to preserve nature's ability to absorb and store carbon, it is vital to restore damaged ecosystems and preserve at least 30 to 50 per cent of terrestrial, freshwater and marine habitats.[15]

1.2 Consequences and economic costs of climate change in Germany

Since 1881, the long-term temperature trend in Germany has increased by 1.6°C (see Figure 03).[16] The ten-year period 2011 to 2020 was around 2°C warmer on average than the reference period 1881 to 1910. The rate of temperature increase has also risen significantly in Germany (and worldwide). Nine of the ten warmest years since 1881 have occurred after the year 2000.[17] The Climate Impact and Risk Assessment 2021 produced by the German Environment Agency (UBA) projects a possible further temperature rise for Germany of 0.9 to 4.7°C by the end of the 21st century.

An increase in hot days with temperatures over 30°C and a decrease in ice days, i.e. days when the temperature remains below 0°C, can also be observed. Figure 04 provides an overview of selected climate change impacts and the observable trends in developments to date.

Figure 03: **Increase in the annual average temperature in Germany since weather records began**



Source: DWD (2022a)

Extreme weather events are occurring more frequently in Germany too – with severe consequences. The current winter weather assessment by the German Weather Service (DWD) shows that the winter of 2021 / 22 was one of the seven warmest winters since continuous weather recording began in 1881, while also being the 11th winter in a row that was too warm.[18] Furthermore, reduced precipitation in 2018, 2019 and 2020 resulted in a drought that was unprecedented in the past 250 years.[19] At the same time, heavy rainfall events may increase. In 2021, extremely heavy rainfall resulted in a flood disaster in the regions around the Ahr and Erft rivers in Germany. The floods claimed the lives of at least 180 people and caused considerable damage. This highlights the risks that extreme weather can pose, especially if these events increase in intensity and frequency in the future.[20]

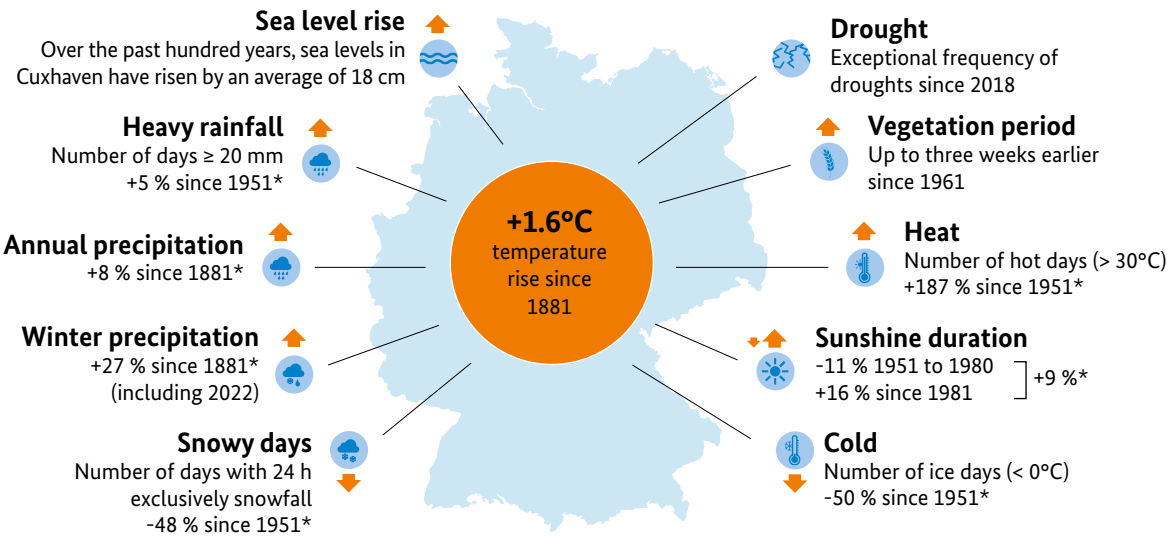
+1.6°C

Since 1881 the long-term temperature trend in Germany has already increased by 1.6 degrees.

Climate change acts as an additional stress factor on natural systems and resources. Natural systems such as groundwater, soil or ecosystems are already under threat due to growing demands placed on them by humans. A gradual rise in temperature and extremes such as heat, drought or strong winds impose an additional stress. Impacts are particularly severe on biodiversity. Already one third of species found in Germany are endangered.[21] Plants and animals are particularly sensitive to changes in the climate. Heat and drought stress make trees more vulnerable to strong winds, heavy rain or forest fires. Pests such as the spruce bark beetle benefit from the weakening of trees and rising temperatures (see also Section 3.8). An area roughly the size of the Saarland, Bremen and Berlin together (380,000 hectares) now has to be reforested.[22] The costs of the necessary reforestation and adaptation measures are estimated to run into the billions of euros.[23] The Federal Government is supporting private and municipal forest owners with a financial aid package worth around 1.5 billion euros.[24]

Climate change also poses a multitude of risks to society and the economy. Climate change has a direct impact on the health of vulnerable population groups in Germany. This is particularly noticeable in cities. Due to high densification, heat waves cause prolonged heat stress. This can result in heat-related deaths, especially among older people and those with pre-existing medical conditions. Extreme weather also affects infrastructure and buildings. In cities, the high degree of surface sealing often results in flooding after heavy rainfall, affecting the water supply and sewage system, as well as the energy supply and transport. In addition, there are growing risks to the economy. Sectors of the economy that utilise nature – such as agriculture and fisheries – are particularly affected.

Figure 04: **Trends in selected climate change impacts in Germany**



*Ratio of the linear trend from 1951 (or respectively 1881, 1981) to 2021 to the mean value of the reference period from 1961 to 1990

Sources: BSH (2022), DWD (2022a), DWD (2022b)

2. Climate policy in Germany, Europe and the world

Summary

According to the Federal Climate Change Act (hereinafter Climate Change Act), Germany will become greenhouse gas neutral by 2045. All necessary laws and measures are to be introduced before the end of 2022 to bring all sectors onto the target path.

With the European Climate Law, the European Union has made a commitment to achieving climate neutrality by 2050. The final cover text from COP 26 – the 2021 climate conference in Glasgow – reaffirmed the goal of limiting global warming to 1.5°C as far as possible.

	Climate targets	Key strategies and instruments
Germany	2030: At least -65 % 2040: At least -88 % 2045: Greenhouse gas neutrality From 2050: Negative emissions	Climate Change Act, climate action programmes such as the Immediate Climate Action Programme from 2022
Europe	2030: At least -55 % 2050: Climate neutrality	European Climate Law, European Green Deal, EU emissions trading, Effort Sharing Regulation, Fit for 55 package
Global	Limit global warming to well below 2°C, preferably 1.5°C	Paris Agreement, Nationally Determined Contributions (NDCs), Green Climate Fund

2.1 German climate policy

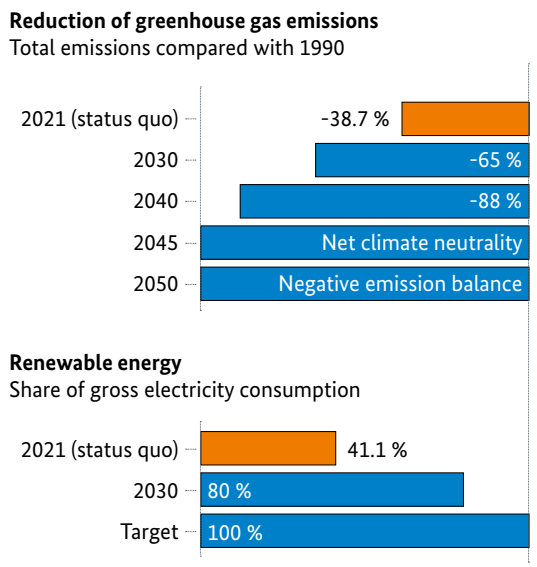
Under the Climate Change Act, Germany must become greenhouse gas neutral by 2045. By then at the latest, no more emissions harmful to the climate may be released than can be absorbed, for example by carbon sinks like forests and peatlands. By 2030, greenhouse gas emissions are to be reduced by at least 65 per cent compared with 1990. The new national climate action target of at least an 88 per cent reduction applies for the year 2040 (see Figure 05). These goals require almost a tripling of the current rate of emission reduction by 2030. While emissions have fallen by an average of 15 million tonnes per year over the past decade, they will have to fall by 36 to 41 million tonnes every year from now until 2030.[25]

By defining annual emission volumes, which the sectors must not exceed, the Climate Change Act specifies the emission reductions that individual sectors must contribute annually until 2030 (see also Figure 11 in Section 3.1). Cross-sectoral annual reduction targets are set for the years 2031 to 2040, based on which the annual emission levels permitted for each sector during that period will be decided in 2024.

To systematically align German climate policy with the 1.5°C target and therefore with the goals of the Climate Change Act, a course correction is necessary. According to current scientific estimates in the Federal Government's 2021 forecast report, the measures implemented so far will only achieve an emissions reduction of about 50 per cent by 2030 (67 per cent by 2040). This means that between 2021 and 2030, the set emissions ceilings would be exceeded by more than one gigatonne (1,000 million tonnes) CO_2 equivalent – i.e. by more than a whole year's worth of emissions at current levels.[26]

The Immediate Climate Action Programme will bundle all the required measures, and all the necessary laws are to be introduced before the end of 2022. The goal of the Immediate Action Programme is to bring all sectors onto the target path so that Germany can achieve its climate goals. In July 2022, the Bundestag and Bundesrat passed an "Easter Package" of energy policy measures that the Federal Government had presented in the spring. In doing so, it brings forward particularly urgent measures from the Immediate Action Programme. The Easter Package implements much of the energy policy content of the coalition agreement, and initiates the largest energy policy revision in decades (see info box in Section 3.2). The Federal Government will implement the remaining measures in the Immediate Action Programme in the near future.

Figure 05: **Federal Government energy and climate targets**



Sources: Federal Government (2022c), Federal Government (2021c), UBA (2022a), UBA (2022b)

The new Federal Government will consistently develop further amendments to the Climate Change Act and also review compliance with the climate targets on the basis of a cross-sectoral and multi-year overall account. The basis for this is the existing annual monitoring. In addition, in the future new draft laws are to be subjected to a "climate check" for their climate impact and compatibility with the national climate action targets.

Reaching the 1.5°C target path requires, among other things, a massive expansion of renewable energy. Renewable energy sources will gradually replace fossil fuels in all sectors, covering a rising demand for electricity that will result from increasing electrification. As determined in the Easter Package of energy policy measures, renewables should make up 80 per cent of gross electricity consumption in 2030 (see Figure 06). With the completion of the coal phase-out, the goal is then to generate almost all of Germany's electricity

-65 %

By the year 2030 emissions of greenhouse gases are to be reduced by at least 65 per cent compared with 1990 levels.

from renewable energies. Further information on the current status and planned expansion of renewable energy sources can be found in Section 3.2.

To achieve the climate targets, the expansion of renewables must be combined with a reduction in energy consumption. In this respect, Germany has not progressed rapidly enough in recent years. Although energy consumption in 2020 and 2021 was lower than in previous years, this was due to the ongoing impact of the COVID-19 pandemic on energy usage and overall economic activity in Germany. Between 2008 and 2019, final energy consumption decreased by only around two per cent. To reach the climate targets by 2030, however, a much greater decrease of 20 to 25 per cent is required. For this reason, the Federal Government plans to create a suitable legal basis for energy efficiency policy at national level in parallel to ongoing negotiations on the amendment of the EU Energy Efficiency Directive.

Expanding renewables and increasing energy efficiency strengthen Germany's energy security. The Russian attack on Ukraine's territorial sovereignty, in violation of international law, highlights the link between security and energy supply. Impacts of the war are also being felt in the form of rising energy prices in Germany and internationally. Dependence on fossil fuel imports from Russia can be reduced by diversifying energy sources and, above all, by accelerating the energy transition to gain greater energy sovereignty. The shift away from fossil energy sources and increases in energy efficiency should be implemented and accelerated in all sectors – from industrial production to mobility and agriculture. In the event of a further escalation of the situation on the energy markets, the Substitute Power Plant Maintenance Act (Ersatzkraftwerkebereithaltungsgesetz, EKBG) and amendments to the Energy Security Act (Energiesicherungsgesetz, EnSiG) were passed at the same time as the Easter Package.

Another cross-sectoral challenge is competing demand for sustainable biomass, of which only limited quantities are available. Its use as an energy source or as a material is an attractive option in various sectors. However, greater biomass use runs contrary to the strengthening of natural sinks that is stipulated by law. The Federal Government therefore envisages the development of a sustainable biomass strategy.

An effective and cost-efficient climate policy requires that government incentives and public spending are brought into line with climate goals. Under the coalition agreement, subsidies and expenditures that are harmful to the climate are to be cut, thus creating additional financial flexibility (see also Section 4.5). The Federal Government also plans to develop the Energy and Climate Fund into a Climate and Transformation Fund (KTF), and to increase the fund's financial resources in the 2022 budget. Additional climate action measures and measures to transform the German economy will be financed in this way. Since 1 July 2022, the levy from the Renewable Energy Sources Act (EEG levy) has been fully financed from the Federal budget, reducing electricity prices for domestic consumers. Low-income households will also receive additional support in the future to reduce their energy consumption and hence their energy costs.

The public sector has to set an example in Germany's transformation towards greenhouse gas neutrality. Therefore, a modern energy management system should be installed as a matter of course in all larger public buildings as soon as possible. Another goal is to make the Federal administration climate-neutral by 2030. An action programme to this end will be presented by 2023. In the meantime, concrete pilot projects will be launched in the relevant areas of action, such as government properties and buildings. Unavoidable greenhouse gas emissions are to be offset.

2.2 European climate policy

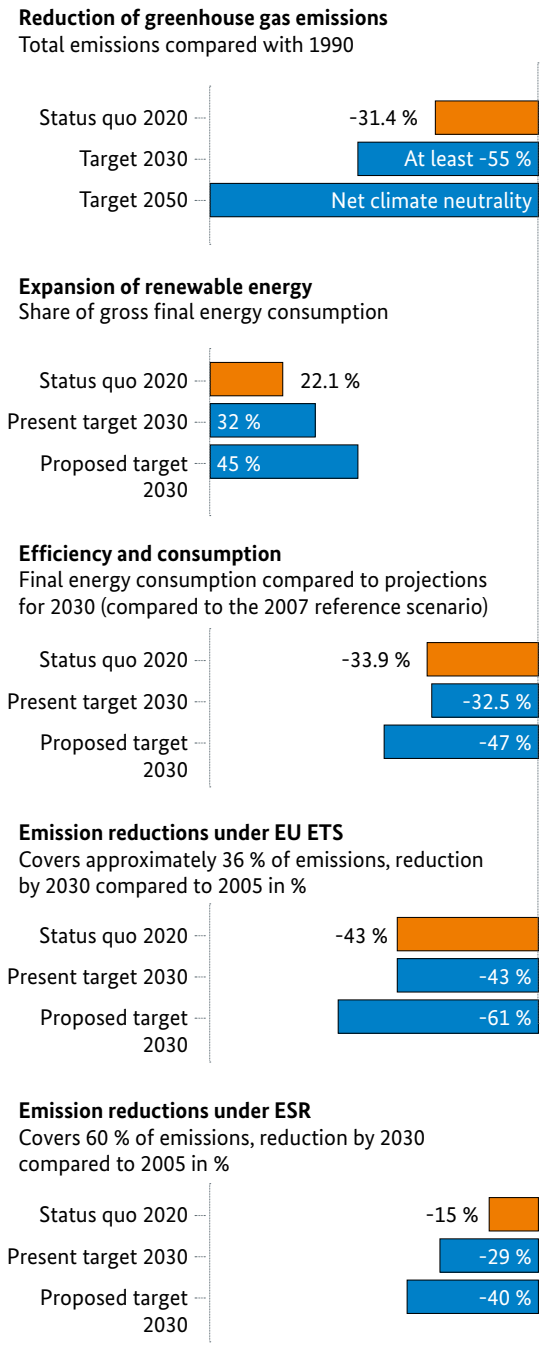
The European Green Deal sets out the European Union's comprehensive strategy for the transformation towards climate neutrality. Its goal is to transition to a sustainable and competitive economy, with a decoupling of growth and resource use. Reshaping the economy is closely linked to action on the climate, environment and biodiversity. In the transformation towards climate neutrality, no-one should be left behind and no region left out. Areas of action include measures for sustainable transport, the third industrial revolution, the transformation of the energy system, the refurbishment of buildings, the protection and restoration of nature, and the revitalisation of biodiversity.

The European Climate Law sets out the EU's overarching climate targets. The Member States have made a legally binding commitment to cut greenhouse gas emissions to net zero by 2050, making Europe the first climate-neutral continent. After that, any residual emissions must be offset by processes that remove greenhouse gases from the atmosphere. As an interim target, greenhouse gas emissions are to be reduced by at least 55 per cent from 1990 levels by 2030 (see Figure 06).

Overall, the EU's greenhouse gas emissions were down 24 per cent in 2019 compared with 1990, and by about 34 per cent in 2020 due to the pandemic. However, the European Environment Agency anticipates that the measures implemented and planned across the EU to date will only achieve an emissions reduction of 41 per cent by 2030. To close the resulting "climate gap" of around 15 percentage points, Germany and the other Member States must implement further measures at national level.[27]

With the Fit for 55 package, the EU is strengthening its climate and energy policy instruments to achieve the raised climate targets and in particular the minus 55 per cent target. The package of measures contains 17 legislative proposals by the European Commission, including a new EU-wide emissions trading scheme for the transport and buildings sectors, adjusted targets at Member State level and offsetting measures. The existing EU Emissions Trading System (EU ETS) needs to be revised to implement the increased reduction target for 2030. The EU ETS caps the majority of emissions in the energy and industrial sectors,

Figure 06: **EU energy and climate targets**



Sources: EEA (2021a), EEA (2021b), EEA (2022), European Commission (2021a), European Commission (2022), Eurostat (2021a), Eurostat (2021b), Eurostat (2022)

as well as intra-EU aviation emissions. This covers around 36 per cent of greenhouse gas emissions in the EU.[28] By 2030, emissions in these sectors are to be reduced by 61 per cent compared with 2005 levels (see Figure 06). A new measure proposed by the European Commission is a separate, second emissions trading system specifically to price emissions from the road transport and buildings sectors.

The Effort Sharing Regulation (ESR) – the second overarching pillar of EU climate policy alongside the EU ETS – is also being revised. It sets binding contributions by Member States to emission reductions in those sectors that are not covered by the existing EU ETS. These include the transport, buildings, agriculture and small industry sectors. Together, these account for almost 60 per cent of the EU's greenhouse gas emissions.[29] By 2030, emissions in these sectors are to be reduced by 40 per cent from 2005 levels. The higher overall target means that individual EU Member States' targets under the ESR also have to be revised.

As part of the Fit for 55 package, other key instruments to achieving the climate targets are being revised. Russia's attack on Ukraine has underlined the urgency of climate-neutral transformation, also as a way of ensuring energy security. Against this background, the REPowerEU plan pursues the goal of reducing demand for Russian gas by two thirds by the end of 2022, and making the EU completely independent of fossil fuels from Russia well before 2030. To achieve this, the European Commission has proposed a tightening of the targets under the Fit for 55 package, and launched new initiatives, including measures to encourage energy savings, accelerate the expansion of renewable energy sources and diversify energy imports.

The Fit for 55 package is currently being negotiated between the European Commission, the European Parliament and the Council of Ministers, and is expected to be finally adopted before the end of 2022.

At the European Council meeting of energy ministers at the end of June 2022, it was agreed to raise the previous renewables target from 32 to 40 per cent by 2030. With the REPowerEU plan, the European Commission proposes even more ambitious targets. It states that the share of renewable energy sources in final energy consumption in the EU should be increased to 45 per cent by 2030 (see Figure 06). This will be achieved via an amendment to the Renewable Energy Directive, which covers electricity generation, heating and cooling, and road transport. Under the Commission's proposal, the scope of the Directive will be extended to include air and sea transport. In addition, separate sub-targets are to be introduced to accelerate renewable hydrogen production and tighten requirements for biofuel sustainability. In general, the expansion of renewable energy and the phasing out of coal are expected to make a significant contribution on the path to a climate-friendly economy. After all, more than 75 per cent of greenhouse gas emissions in the EU can be traced back to the energy system.[30]

When it comes to energy efficiency, the European Commission proposes a binding reduction in the EU's energy consumption by 13 per cent by 2030 compared to the 2020 reference scenario. This represents a saving of 47 per cent compared to the previous 2007 reference scenario (see Figure 07). Accordingly, final energy consumption in 2030 should not exceed 750 million tonnes oil equivalent in 2030 (equating to primary energy consumption of 980 million tonnes). In 2020, final energy consumption was still just under 907 million tonnes oil equivalent.[31] To meet the target, Member States should commit to reducing their final energy consumption by 1.5 per cent annually from 2024 onwards (instead of 0.8 per cent as previously planned).

There are further concrete requirements, e.g. for the buildings sector. Here the European Commission proposes a legal obligation for three per cent of all public buildings to undergo energy refurbishment annually, based on floor area. In addition, the amendment to the Building Efficiency Directive aims to introduce minimum standards for existing buildings together with associated refurbishment obligations, as well as a solar roof obligation particularly for new buildings.

Through regulatory standards and the EU ETS, the EU has become a driver of climate policy in Germany. The swift conclusion of negotiations on the Fit for 55 package is a top priority for the Federal Government so that the respective climate action instruments can enter into force as soon as possible.

2.3 International climate policy

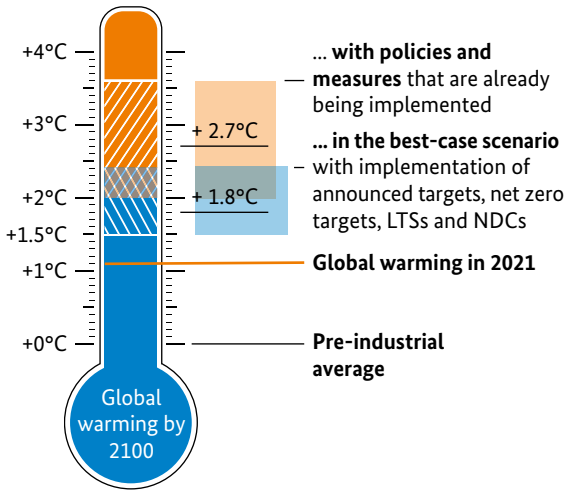
The Federal Government places climate policy at the top of its diplomatic agenda.[32] Under the German presidency, it was decided at the G7 Summit in June 2022 to establish an open and cooperative "climate club" by the end of the year. The aim is to advance the implementation of the Paris Agreement. Particular attention will be paid to the industrial sector in order to mitigate the risks of carbon leakage in emission-intensive goods despite compliance with international regulations. Moreover, multilateral Just Energy Transition Partnerships (JETPs) are to mobilise further support for developing and emerging countries in decarbonising their energy systems.

German support for global decarbonisation and ambitious national climate action measures will also be a core topic in dialogue with China and in cooperation with other large emerging economies such as India, Indonesia, South Africa and Brazil. The International Climate Initiative (IKI) has been financing climate action, climate adaptation and biodiversity projects in developing and emerging countries since 2008. Since its foundation, the IKI has supported a total of over 800 projects in more than 60 countries with a funding volume of around five billion euros. To share important experience, Germany also exchanges information on the energy transition and climate action with more than 25 partner countries within a framework of climate and energy partnerships and dialogues. The Federal Government plans to continue to promote these climate and energy partnerships, and initiate new ones. In this context, there is also an increasing focus on supplying Germany with climate-neutral energy sources such as green hydrogen.

Industrialised countries like Germany bear a particular responsibility in the fight against climate change. Historically, Germany is responsible for 4.6 per cent of global greenhouse gas emissions. Since the start of industrialisation, the current industrialised countries have caused more than half of all greenhouse gas emissions. In emerging countries such as China and India, emissions have risen sharply only in recent decades. The largest emitters in 2019 included China, the United States, the EU, India and Russia. Per capita emissions in wealthy nations are still higher than in most emerging and developing countries. In 2020, the average annual CO_2 footprint per person in Germany was 7.7 tonnes of CO_2 emissions – once again significantly above the global average of 4.6 tonnes. Citizens of the EU27 emitted an average of 5.9 tonnes of CO_2 in the same year.[33]

Figure 07: **Ambition gap to global 1.5°C target**

Projected temperature rise by the year 2100...



Sources: Climate Analytics, NewClimate Institute (2021), WMO (2022)

With the Paris Agreement, the international community committed itself to climate action. At the Paris climate change conference (COP 21) in December 2015, the parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed to limit global warming to well below 2°C, with a target of 1.5°C. The final cover decision from COP 26 in Glasgow reaffirms the goal of limiting global warming to 1.5°C, and states that achieving this requires reducing carbon dioxide emissions by 45 per cent by 2030 relative to the 2010 level.[34] Almost 200 countries joined the Glasgow Climate Pact, which aims to make the 2020s a decade of climate action and support measures.

Other agreements reached at COP 26 include a significant phasedown of coal power and phase-out of inefficient fossil fuel subsidies. Furthermore, a transnational

-45 %

To limit global warming to 1.5 degrees by the end of the century, global carbon dioxide emissions must, among other things, be reduced by 45 per cent by 2030 compared to 2010.

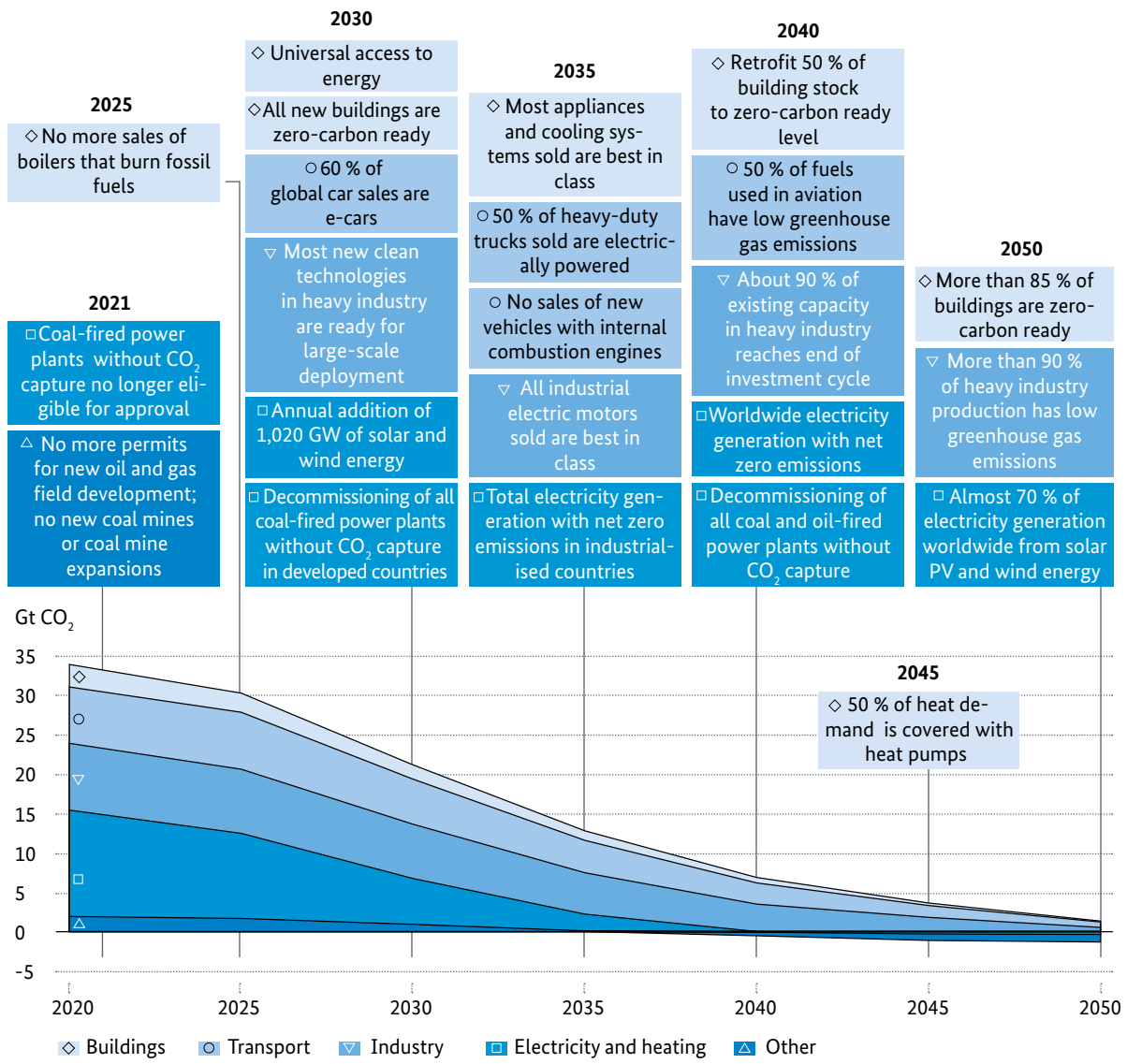
carbon market is to be established and reporting obligations for climate action efforts introduced. Countries also made voluntary commitments in various areas (including coal phase-out, transport, forest protection and land use). For example, 137 countries have committed to halting and reversing forest loss and soil degradation by 2030. Another alliance of 103 countries signed a new international agreement to cut methane emissions (Global Methane Pledge). Fifteen major emitters agreed to reduce methane emissions by 30 per cent from 2020 levels by 2030.

Despite international efforts, there is still a significant shortfall to the 1.5°C target, especially with regard to implementation. Based on the policies actually implemented at present, the projected global temperature increase by 2100 is 2.7°C (see Figure 07). With the implementation of all targets already announced (including net zero targets), long-term strategies (LTSs) and NDCs, a temperature increase of 1.8°C by 2100 is predicted. Therefore, by the time of the next climate conference (COP 27) in Egypt in 2022, the parties are called upon to adjust their 2030 goals accordingly and present LTSs leading to net zero emissions by the middle of the century.

Climate finance will be one of the key topics at COP 27 in Egypt. It became clear in Glasgow that the industrialised countries had not honoured their promise to deliver a total of 100 billion US dollars annually to help developing countries by 2020. For this reason, in 2021 Germany pledged to increase its contribution from four to six billion euros by 2025. Another focus at COP 27 will be the new climate finance target for the period after 2025.

The International Energy Agency (IEA) presented a global 1.5°C pathway for the first time in May 2021. The report covers all energy-related CO_2 emissions from the energy, industrial, buildings and transport sectors. It sets out the ambitious milestones for a global path towards CO_2 neutrality in 2050 (see Figure 08). The expansion of renewable energy sources to more than 1,000 gigawatts (GW), representing a quadrupling of the current global capacity, is a priority. At the same time, major progress has to be made in energy efficiency, and coal-fired power stations must be shut down worldwide. In the private sector, the IEA states that no more boilers using fossil fuels should be sold from 2025. From 2035, no new cars with combustion engines should be produced. Despite uncertainties that are always inherent in such longer-term scenarios, the IEA scenario shows how the 1.5°C target could still be achieved.

Figure 08: **Important milestones on the way to net zero according to the IEA 1.5°C pathway**

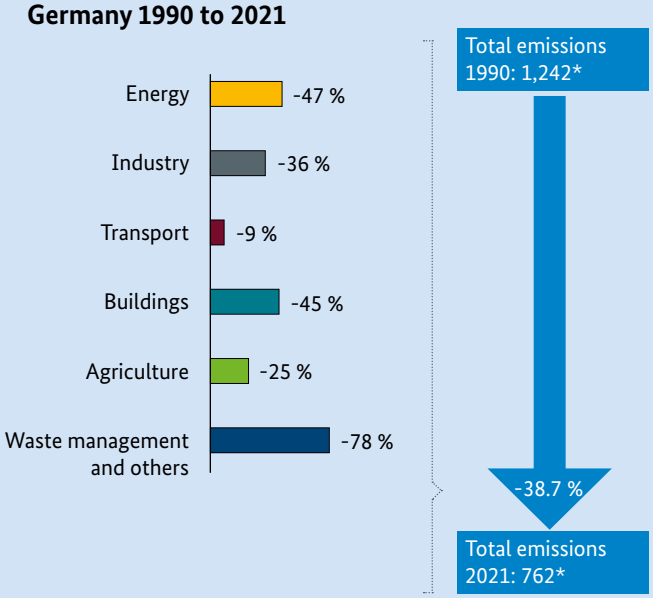


Source: IEA (2022)

3. Emission trends and climate action measures in the sectors

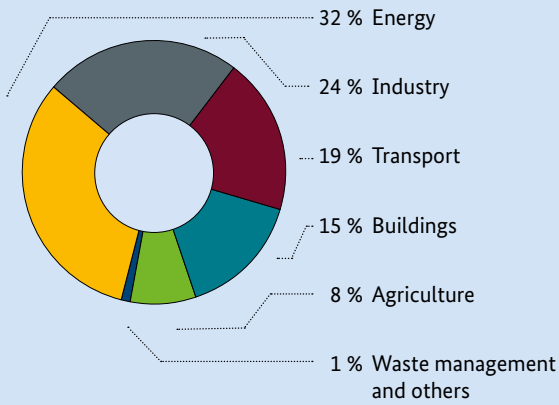
Summary

Greenhouse gas emission trends in Germany 1990 to 2021



Source: UBA (2022c)

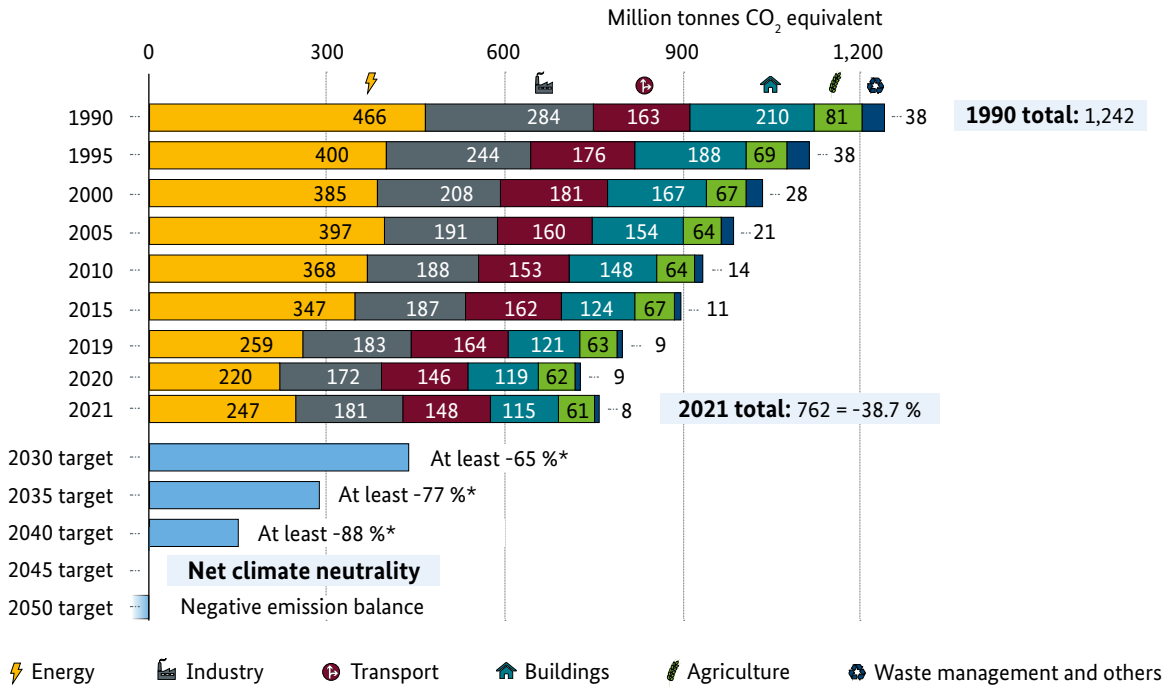
Share of greenhouse gas emissions in Germany 2021



Emissions from the use of fossil fuels account for about 85 % of total emissions.

*Million tonnes CO_2 equivalent

Figure 10: **Greenhouse gas emission trends in Germany by sector (excluding LULUCF)**



*Reduction targets compared with 1990

Sources: Federal Government (2021c), UBA (2022c)

3.1 Emissions in Germany – past, present and future

Greenhouse gas emissions in Germany decreased by roughly 38.7 per cent between 1990 and 2021 (1990 to 2020: -40.8 per cent) (Figure 10). In absolute figures, Germany's emissions decreased from 1,242 million tonnes CO_2 equivalent in 1990 to roughly 762 million tonnes CO_2 equivalent in 2021. By 2030, Germany intends to reduce emissions by 65 per cent, to a maximum of 435 million tonnes CO_2 equivalent.

Compared with the previous year, however, Germany's greenhouse gas emissions in 2021 increased by 33 million tonnes CO_2 equivalent, or 4.5 per cent. This increase is predominantly due to the energy sector generating more coal-based power. Reasons include the increase in the electricity demand, a reduction in the amount of electricity generated by renewable energy sources and the higher gas prices in 2021 (see also Section 3.2).[35]

Annual greenhouse gas emissions are influenced by climatic and economic fluctuations. Fluctuating weather conditions in particular reduce or increase the demand for heating from year to year. For example, 2020 was an unusually mild year, especially in winter, while the average temperature in 2021 was below the long-term average. Macroeconomic factors have caused greenhouse gas emissions to decrease, for example, as a result of the economic upheaval in the Federal States of the former East Germany in the early 1990s, during the 2009 financial and economic crisis, and most recently as a result of the impact of the COVID-19 pandemic.

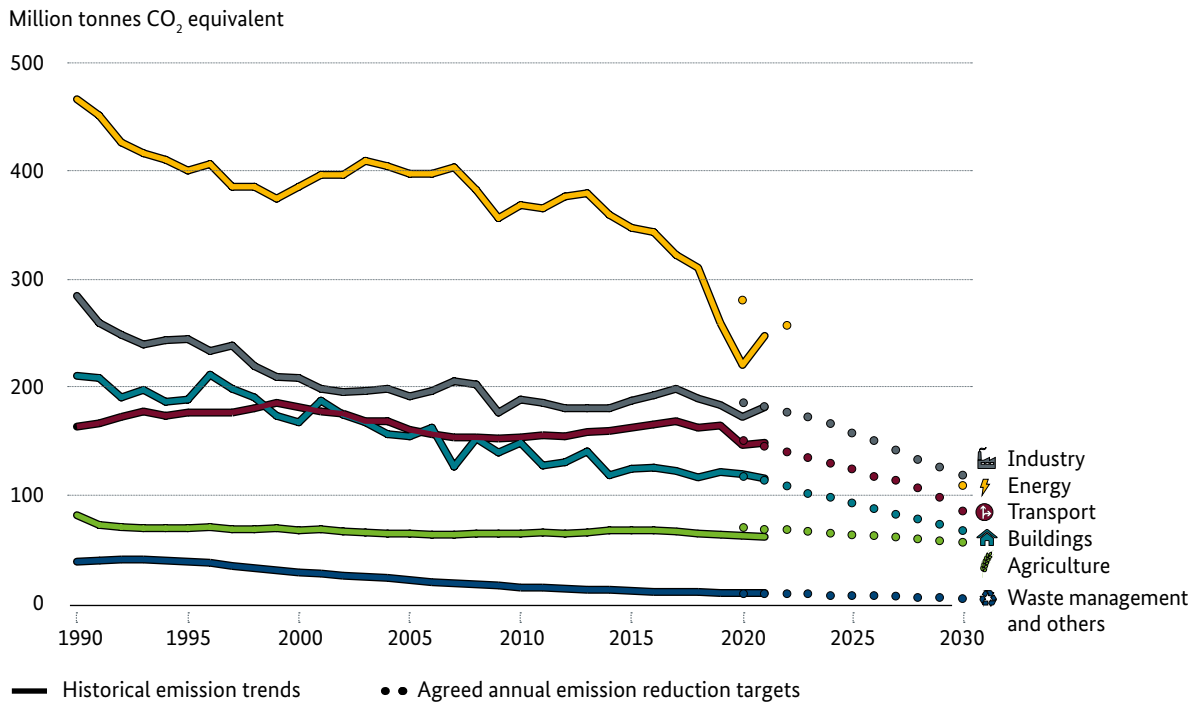
This brochure presents greenhouse gas emissions based on the source principle. Emissions are attributed to the sector in which they first originate. For example, all emissions from public electricity and district heat generation are attributed to the energy sector, even if the electricity or heat is used in the buildings sector.

In 2021, emissions from the transport and buildings sectors were both just above the annual emission levels prescribed in the Climate Change Act. The annual reduction targets specify the reduction path for each sector from 2020 to 2030 (Figure 11). In 2021, the industry, agriculture and waste and recycling management sectors emitted less than the permissible annual emission volumes. For the energy sector, no target value was defined for 2021, only for 2020 and 2022. At 247 million tonnes CO_2 equivalent, the energy sector's emissions were 12.4 per cent higher than in the previous year, but 10 million tonnes CO_2 equivalent below the target value for 2022 (257 million tonnes CO_2 equivalent).

Emissions will need to be reduced by six per cent each year to achieve the Federal Government's climate targets by 2030. On average, emissions have fallen by less than two per cent each year since 2010.[36] As laid out by the Climate Change Act mechanism, the Council of Experts on Climate Change (ERK) reviews the emissions data calculated annually by the German Environment Agency (UBA). As last year, the Council of Experts confirmed both the consistency of the data published by the UBA for 2021 and the complex methodology used to calculate it. The Council therefore verified that the buildings and transport sectors had missed their targets. As prescribed in the Climate Change Act, the responsible federal ministries each submitted an immediate action programme three months later, on 13 July 2022, to bring the two sectors onto the specified target path in the coming years. The Council of Experts will also examine these programmes to determine whether the measures contained within them are sufficient to ensure compliance with the targets for the transport and buildings sectors in the following years. Independently of this, the Federal Government continues to work on a comprehensive Immediate Climate Action Programme across all sectors.
The proposed measures contained in the immediate action programmes shall be integrated into the overall programme at a later date.

In the second part of its expert report, the ERK has proposed further developing Germany's Climate

Figure 11: **Greenhouse gas emission trends and agreed sector-specific annual targets by 2030**



Sources: Federal Government (2021c), UBA (2022c)

Change Act. For instance, it suggests that greater account should be taken of one-off effects specific to particular years, such as the recently very high fuel prices. In addition, the Council of Experts argues in favour of retaining sector-specific targets, as these distribute the burden among the sectors more fairly and enable political responsibility to be assigned to the respective federal ministries.

3.2 Energy sector

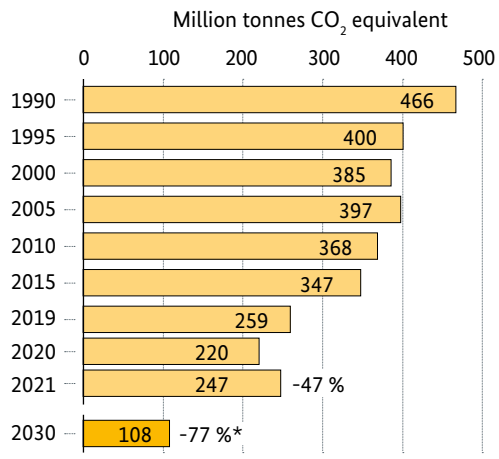
Emission trends

At 32 per cent, the energy sector is responsible for the largest share of emissions in Germany. In 2021, its greenhouse gas emissions totalled 247 million tonnes CO_2 equivalent. This figure equates to a reduction of 47 per cent compared with 1990 (Figure 12). In order to achieve the sector target for 2030, emissions will need to be more than halved again compared with the current level. This is to be ensured with the Easter Package of immediate energy measures and other measures envisaged in the Immediate Climate Action Programme.

Emissions from the energy sector are largely caused by power plants burning fossil fuels to supply electricity and heat to the public (Figure 13). Emissions from refineries and fossil fuels transported in pipelines, as well as "diffuse emissions", are also attributed to the energy sector. These are caused, for example, by the release of mine gas from decommissioned mines.

Greenhouse gas emissions from the energy sector increased in 2021 for the first time since 2013. Compared with the previous year, the sector's emissions increased by 27 million tonnes CO_2 equivalent, a rise of 12.4 per cent. This was partly due to the electricity demand increasing by 1.9 per cent to 565 terawatt hours (TWh), after demand had fallen significantly in the previous year due to the COVID-19 pandemic. In addition, the previous year's weather-related record high for electricity generated from renewable energy sources was not reached again. Instead, the increased demand was met by electricity generated from fossil energy sources. In particular, the electricity generated from lignite and hard coal as emission-intensive energy sources increased significantly compared with the previous year. This illustrates that the order in which power plants burning fossil fuels are used is primarily determined by two factors: the prices of energy sources such as coal and gas and the prices for allowances in the EU ETS. The very sharp rise in gas prices in the second half of 2021 meant that coal-fired power plants were used more frequently than the lower-emission gas-fired power plants. And this despite the fact that allowance prices continued to rise in 2021.[37]

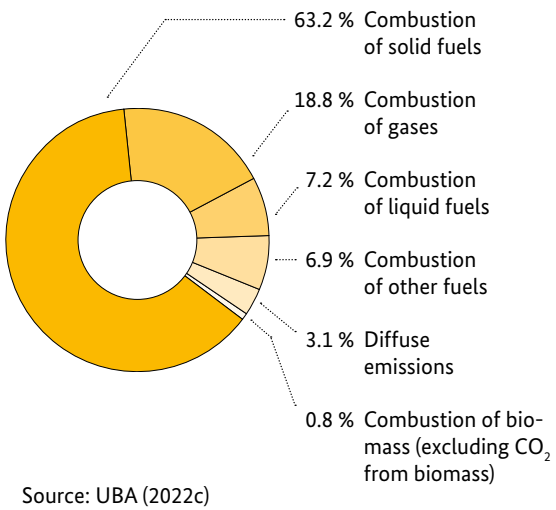
Figure 12: **Emission trends in the energy sector**



*Reduction target compared with 1990

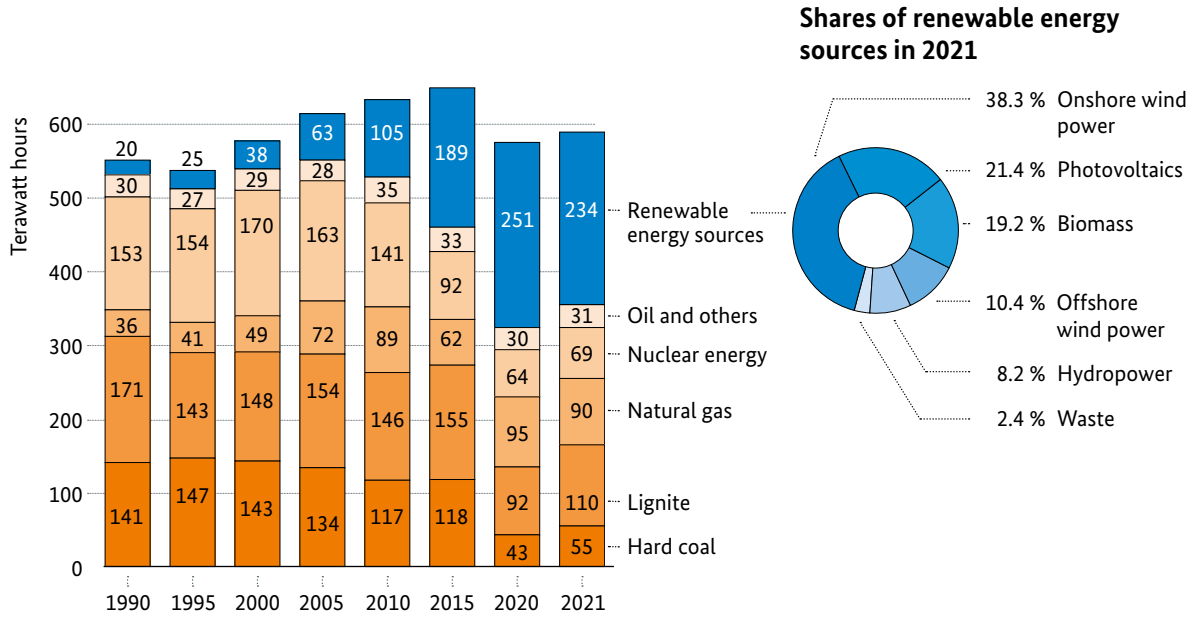
Sources: Federal Government (2021c), UBA (2022c)

Figure 13: **Sources of emissions in the energy sector (2020)**



Source: UBA (2022c)

Figure 14: **Trend in gross power generation by energy source**



Source: BMWK (2022a)

The proportion of electricity generated from renewable energy sources has risen sharply since 1990 (Figure 14). Photovoltaics (PV) grew particularly fast between 2009 and 2012. The installed onshore wind energy capacity rose fastest between 2013 and 2017. Offshore wind energy has also grown significantly in recent years.

After the record-breaking year 2020, 2021 saw a decline in the absolute and relative proportion of electricity generated from renewable energy sources for the first time since 2000. In 2021, 234 terawatt hours of electricity were generated from renewable energy sources – 17.5 terawatt hours less than in the previous year – thus covering 41.1 per cent of the gross electricity consumption.[38] Renewable electricity generation therefore fell short of the previous year's peak value of 45.2 per cent, which is due to an increase in the electricity demand and the weather-related decline in electricity generated from onshore and offshore wind energy. The effect of the decline also overshadowed a further – albeit small – increase in new renewable energy capacities.

Among renewable energy sources, onshore wind energy contributed the most to the gross electricity generation, with a 15.2 per cent share. This corresponds to a 38.3 per cent share of renewable energy sources (Figure 14). Biomass and PV contributed 7.6 and 8.5 per cent respectively to the gross electricity generation. Offshore wind energy and hydropower have significantly lower shares amounting to 4.1 and 3.2 per cent respectively.

The sharp decline in electricity generated from coal up to 2020 was followed by a resurgence for the first time last year. In 2021, the electricity generated from coal increased by 30.4 terawatt hours or 22.6 per cent compared with the previous year. Lignite therefore once again made the largest contribution to generating electricity in 2021, and not wind energy as in the previous year. Compared with 2015, the electricity generated from lignite and hard coal decreased by around 40 per cent. While coal-fired power stations delivered 272 terawatt hours of electricity in 2015, this figure had fallen to around 165 terawatt hours

-47 %

Emissions from the energy sector in 2021 were 47 % below the 1990 level.

by 2021. This decline has so far been particularly due to an increase in the allowance prices in the EU ETS. As a result, the generation of electricity from coal has been partially replaced by electricity generated from natural gas and renewable energy sources in recent years.

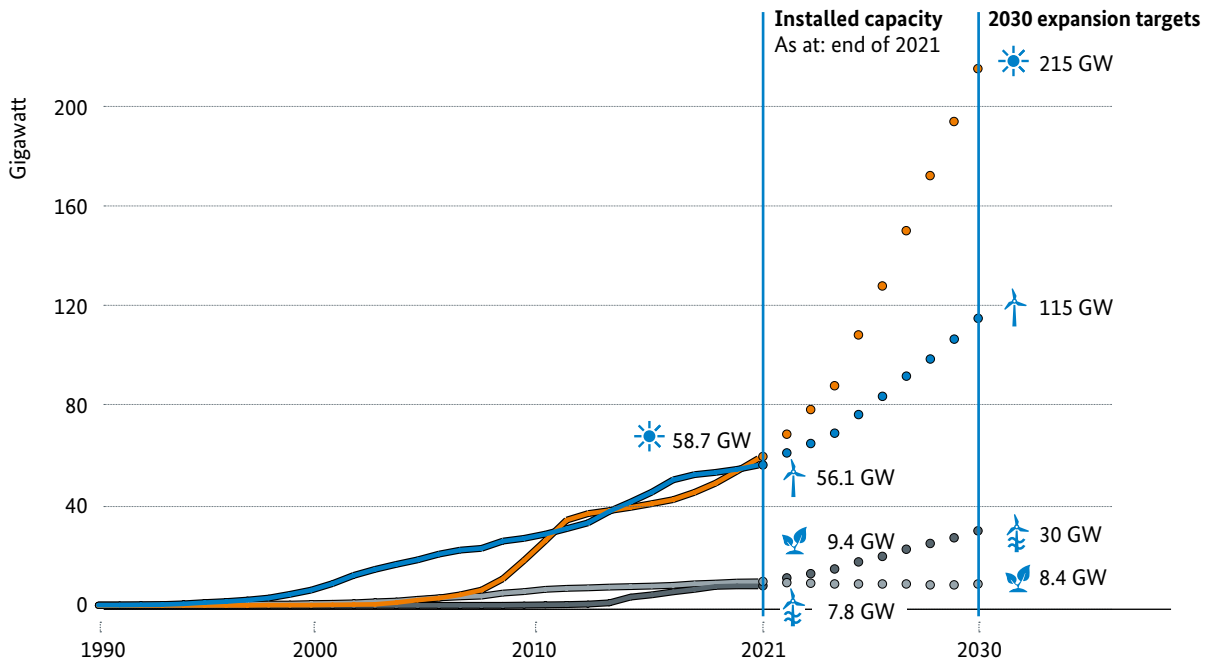
Electricity generated from gas-fired power plants declined slightly by five terawatt hours in 2021, but remains at a high level. The importance of natural gas has, on the whole, increased in recent years. Since 2015, electricity generated from natural gas has risen by approximately 45 per cent. Natural gas still currently serves as a bridge technology for transitioning the energy system to renewable energy sources. Compared with the other fossil fuels – lignite, hard coal and oil – electricity generated from natural gas causes fewer greenhouse gas emissions. Compared with coal-fired and nuclear power plants, gas power stations are far more flexible in operation and are therefore well suited as a transitional technology to compensate for the natural fluctuations when generating power from renewable energy sources.

The percentage of electricity generated from nuclear energy has been in decline since the 2000s. After starting to phase out nuclear energy in 2000 and taking the final decision in 2011, Germany has been decommissioning its power stations one by one since then. At 11 per cent, the electricity generated from nuclear power in 2021 was roughly at the same level as the previous year. Three more power reactor units (Grohnde, Gundremmingen C and Brokdorf) ceased operation at the end of 2021. Germany's last three nuclear reactors will be decommissioned at the end of 2022.

Areas of action and measures

In order to achieve the goal of greenhouse gas neutrality, it is essential to decarbonise the energy supply completely and at an early stage. After all, the electricity sector has a key role to play due to the electrification required in other sectors such as heat and transport – known as sector coupling. Decarbonising the electricity supply, which is set to be completed once coal has been phased out, is essential for achieving

Figure 15: **Past and present renewable energy expansion plans in Germany**



Sources: BMWK (2022b), Federal Government (2022a), Federal Government (2021b)

greenhouse gas neutrality by 2045 in order to meet the growing demand for electricity in the other sectors in the most climate-friendly way possible.

As an interim goal, greenhouse gas emissions in the entire energy sector are to decrease gradually to 108 million tonnes CO_2 equivalent by 2030. In order to achieve this goal and meet the rising demand for electricity, the power generated from renewable energy sources needs to be more than doubled.

The key area for action in the energy sector is the ambitious expansion of renewable energy sources. The info box on page 29 provides an overview of the key measures contained in the 2022 package of immediate energy measures (Easter Package), which is intended to bring the expansion of renewable energy sources on target. This forms the basis of a greenhouse gas neutral electricity system and – compared with other sectors – represents a proven, cost-effective and rapid measure for reducing greenhouse gas emissions. By 2030, the share of renewable energy sources is set to increase to at least 80 per cent of the gross electricity consumption. The Federal Government expects electricity consumption to increase by 2030 to roughly 750 terawatt hours. It follows that in 2030 a total of around 600 terawatt hours needs to be provided from renewable energy sources in Germany. Expansion roadmaps for the individual technologies will be massively increased to achieve this (Figure 15 and info box).

In order to achieve the increased expansion targets, the expansion of renewable energy sources will be significantly accelerated. This had stalled in recent years. Onshore wind energy in particular is experiencing a challenging time. Since the record year of 2017, which achieved a net increase of round 4.9 gigawatts, its expansion has declined sharply due to the limited land available, acceptance problems as well as protracted approval procedures and lawsuits. Most recently there has been a net increase from around 1.2 gigawatts in 2020 to 1.7 gigawatts in 2021.

The expansion of solar energy also declined sharply over a period of several years. While solar energy systems totalling 8.2 gigawatts were built in 2012, this figure had dropped to 1.2 gigawatts by 2014. However, the annual number of newly installed PV systems has risen continuously since then. In 2021, it amounted to around five gigawatts.[39]

Germany's coal phase-out started at the beginning of 2021. With the Coal Phase-out Act (Kohleausstiegsgesetz), the Federal Government drew up a roadmap for gradually phasing out coal-based power generation. For example, lignite and hard coal power plants with respective capacities of around 0.9 gigawatts and 5.5 gigawatts were shut down during 2021.[40] The Coal-fired Power Generation Termination Act (Kohleverstromungsbeendigungsgesetz) defines the decommissioning roadmap for the remaining lignite power plants. For hard coal-fired power plants, on the other hand, the order of decommissioning will be determined primarily through tenders. Only from 2027 onwards will corresponding regulatory measures become effective. The installed generation capacity of coal-fired power plants on the market will be initially reduced from 43.6 gigawatts at the end of 2019 to 30 gigawatts by the end of 2022 and to 17 gigawatts by 2030. The power supply is set to become greenhouse gas neutral once coal has been phased out.

Security of supply is also ensured during the gradual phase-out of coal-based and nuclear power generation. To this end, the Federal Government regularly reviews whether sufficient generation capacities are available even at times of high electricity demand and low feed-in from renewable energy sources. For example, systemically important hard coal-fired power plants are not shut down, but are temporarily transferred to the grid reserve and can be reactivated if necessary. The generation from renewable energy sources needs to be supplemented by flexible power plants that are still temporarily operated with natural gas, but in future will be based on renewable gases. This way the expansion of renewable energy sources will firstly reduce dependence on the import of fossil raw materials. Secondly, renewable energy sources can be used to produce gases such as green hydrogen (see info box), which can be used as energy storage units to ensure supply security even during phases with low

108 million t

By 2030, greenhouse gas emissions from the entire energy sector are to be reduced to 108 million tonnes CO_2 equivalents.

i

Overview of key measures contained in the package of immediate energy measures (Easter Package)

The Easter Package adapts the following laws:

- Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz, EEG),
- Offshore Wind Energy Act (Windenergie-auf-See-Gesetz, WindSeeG),
- Wind Area Requirements Act (Windenergie-flächenbedarfsgesetz, WindBG, currently being newly introduced) and the Town and Country Planning Code (Baugesetzbuch, BauGB)
- Energy Industry Act (Energiewirtschaftsgesetz, EnWG)
- Federal Requirements Plan Act (Bundesbedarfs-plangesetz, BBPlG),
- Transmission Grid Expansion Acceleration Act (Netzausbaubeschleunigungsgesetz Übertra-gungsnetz, NABEG),
- Federal Nature Conservation Act (Bundesnatur-schutzgesetz, BNatSchG)
- as well as other laws and ordinances as part of the energy legislation.

The Easter Package includes the following key changes:

- It enshrines the principle that the use of renew-able energy sources is in the overriding public interest and serves public safety.
- This means that until greenhouse gas neutrality is achieved, renewable energy sources shall be included as a priority concern when weighing up the legitimate interests of protected resources.
- By 2030, it is intended that at least 80 per cent of Germany's gross electricity consumption shall be met by renewable energy sources instead of the current 65 per cent. The power supply is set to become greenhouse gas neutral once coal has been phased out.
- As a result, the expansion targets and tender volumes for the individual technologies will be gradually adjusted and stabilised at a high level of:
    - 22 gigawatts of newly installed PV capacity per year, i.e. an installed capacity target of around 215 gigawatts in 2030,
    - 10 gigawatts per year of newly installed capacity for onshore wind, i.e. around 115 gigawatts of installed capacity in 2030.
    - The installed capacity of offshore wind is targeted to be at least 30 gigawatts in 2030 (40 gigawatts in 2035, 70 gigawatts in 2045).
- The WindBG enshrines in law that two per cent of the land area is required for onshore wind and the Länder are given binding targets for designating land.

In order to achieve the ambitious targets, specific measures will be taken for further expanding renewable energy sources. For example:

- the availability of areas for expanding ground-mounted PV will be improved,
- the participation of municipalities in onshore wind and PV will be expanded,
- the reference yield model for low-wind sites will be further refined, particularly in southern Germany, with the intention of increasing the development of low-wind sites,
- areas that have not been pre-surveyed for the expansion of offshore wind energy will be put out to tender, and
- the framework for expanding PV rooftop sys-tems will be improved.

In addition, in order to accelerate the expansion of the electricity grids:

- simplifications will be enshrined for planning, approving, realising and operating grids,
- the target of greenhouse gas neutrality will also be enshrined in the EnWG and included as a focus in grid planning, and
- new projects will be included in the Federal Requirements Plan for expanding transmission networks.

In order to relieve and strengthen citizens:

- the EEG levy will be abolished and, at the same time, the regulations for self-consumption and the privileged treatment of industry will be extremely simplified, and
- the rights of end customers and the Federal Net-work Agency's supervisory powers over energy suppliers will be strengthened.

Further measures from the Immediate Climate Action Programme will be swiftly initiated in order to get on the target path as quickly as possible and thus achieve the ambitious 2030 climate targets.

feed-in from renewable sources. At the same time as the Easter Package, the EKBG and amendments to the EnSiG were also passed. This has enabled the Federal Government to create additional instruments that can be called upon at short notice, should the situation on the energy markets further deteriorate. The Substitute Power Plant Maintenance Act is intended to establish a gas replacement reserve that will be valid until 31 March 2024. In an emergency, oil- and coal-fired power plants shall produce power if the volume of gas supplies is insufficient to generate enough electricity from gas and there is a gas shortage situation. The goal of phasing out coal in Germany, ideally by 2030, remains in place.

Another key area for action in the energy sector is concerned with modernising the energy supply system. This includes both expanding electricity grids and using digital technologies to make better use of existing grids. In future, pipelines also need to be built for transporting low-emission, gaseous energy carriers such as hydrogen.

i

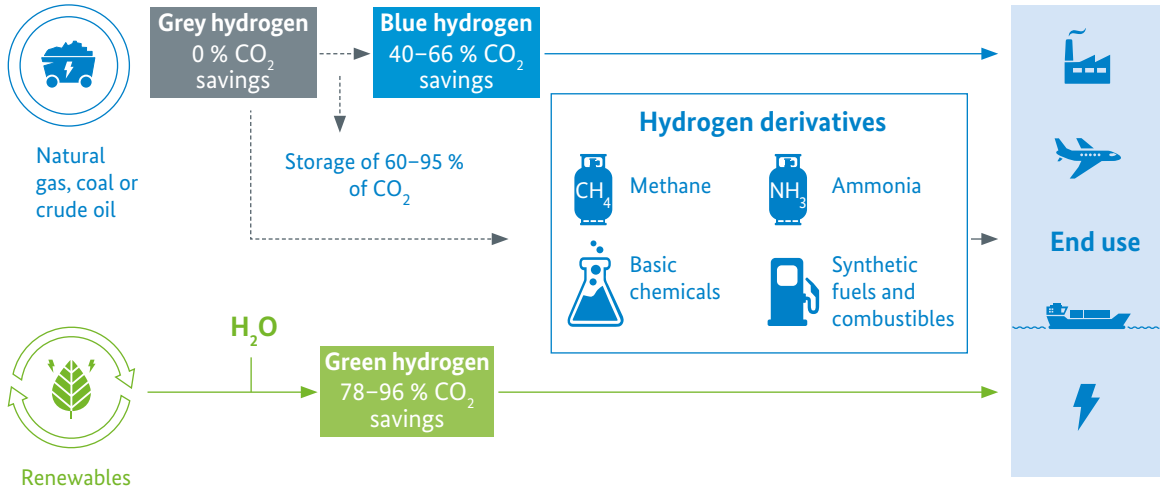
Hydrogen as the energy carrier of the future in a decarbonised energy system

Hydrogen plays an important role en route to greenhouse gas neutrality as an alternative to fossil fuels, especially where other alternatives, such as direct electrification, are not available. There are different production routes for hydrogen, which result in different levels of CO_2 emissions. Currently, hydrogen is primarily produced from fossil natural gas, releasing large amounts of CO_2 (so-called grey hydrogen, see Figure 16). These emissions could be partially captured and stored (carbon capture and storage, CCS). Producing this so-called blue hydrogen could therefore save up to two thirds of emissions. However, this would require an additional energy input, and the reduction in emissions would probably not be sufficient to achieve greenhouse gas neutrality. So-called green hydrogen can be produced by electrolysing water with electricity directly generated from renewable energy sources. This process almost completely eliminates emissions.

Hydrogen produced in a climate-friendly way can be used in areas in which electrification is not technically or economically possible. This includes industry, which needs hydrogen as a chemical raw material or as a fuel for processes that require a very high temperature level. In addition, hydrogen can be “reconverted” to electricity in power plants during periods of low feed-in from renewable energy sources. Furthermore, power-to-X processes can be used to produce CO_2 derivatives such as synthetic fuels and combustibles from hydrogen. These can be used for climate-neutral shipping and aviation.

To ensure a sufficient supply of low-emission hydrogen for the various sectors, the Federal Government adopted a national hydrogen strategy in 2020. It addresses all links in the value chain (production, infrastructure, application) as well as the sectors. For the market ramp-up of green hydrogen, the expansion target for the electrolysis capacity is to be raised to 10 gigawatts in 2030. In addition to the national production of green hydrogen, the import of green hydrogen or derivatives will also play a key role in future.

Figure 16: **Different production methods and uses of hydrogen**



The data on the greenhouse gas emissions saved by blue and green hydrogen indicates relative savings compared to the emissions generated by the production of grey hydrogen (approx. 95 g CO_2 equivalent / MJ). The greenhouse gas emissions from grey hydrogen production consider the entire life cycle, including methane leakage during extraction and transportation of natural gas.

Sources: Agora Energiewende & Guidehouse (2021), Guidehouse (2021)

3.3 Industry

Emission trends

In 2021, the industrial sector accounted for 24 per cent of overall emissions in Germany. In 2021, emissions from the sector increased by 5.5 per cent compared with the previous year to 181 million tonnes CO_2 equivalent. This increase was due to the manufacturing sector recovering from the pandemic-related outages in 2020.

Emissions from industry have fallen by 36 per cent since 1990 (Figure 17). Much of this reduction (75 million tonnes CO_2 equivalent) was achieved in the 1990s, partly due to the economic upheaval in the former Eastern Federal States. In the last 20 years, emissions from the industrial sector have fallen only slightly (16 million tonnes CO_2 equivalent).

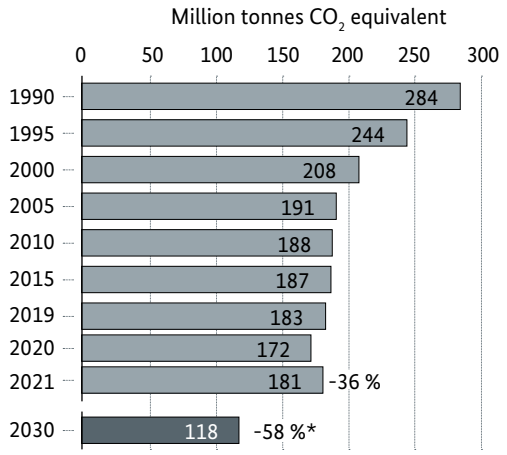
Emissions in industry are primarily generated in energy-intensive sectors such as iron and steel, cement and basic chemicals. About two thirds of the emissions are due to the provision of energy in industry (industrial firing in the manufacturing sector); another third are process-related and arise in the production of basic materials such as cement or pig iron (Figure 18).

In addition to direct emissions, industry also causes indirect emissions through the purchase of external heat and electricity. Together with the energy produced and consumed internally by the industrial sector, this results in the energy consumption shown in Figure 19. Indirect emissions are accounted for in the energy sector, so improving energy efficiency in industry has a positive effect on the emissions balance in the energy sector.

Areas of action and measures

Germany has set itself the goal of reducing greenhouse gas emissions in the industrial sector to a level of 118 million tonnes CO_2 equivalents by 2030. This corresponds to a reduction of 35 per cent compared with the current level. A comprehensive reduction in

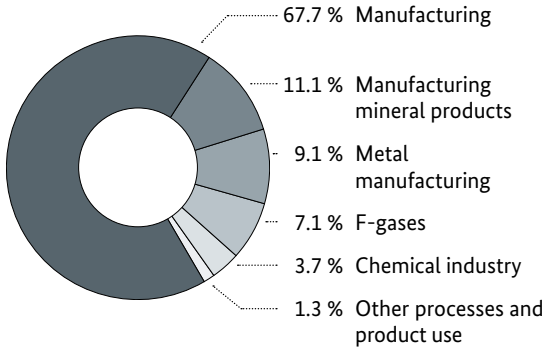
Figure 17: **Emission trends in the industrial sector**



*Reduction target compared with 1990

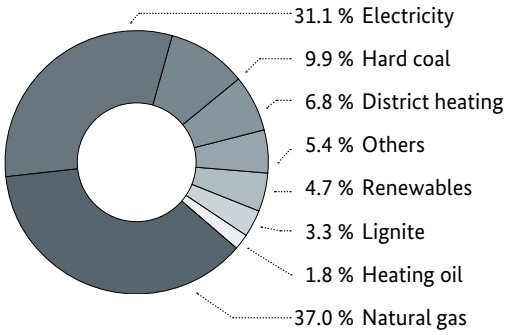
Sources: Federal Government (2021c), UBA (2022c)

Figure 18: **Sources of emissions in the energy industry (2020)**



Source: UBA (2022c)

Figure 19: **Final energy consumption in industry by energy source (2020)**



Source: BMWK (2022a)

industrial emissions requires a change in production processes, especially in the energy-intensive basic industries. The following areas of action are key:

- **Recycling management:** Improved recycling can significantly reduce process- and energy-related emissions. For instance, a high recycling rate can significantly reduce the use of primary materials through the optimised use of resources. In addition, reusing already produced materials requires in part significantly less energy than the primary production of basic materials.

- **Electrification and renewable energy sources:** Electricity demand in the industrial sector is rising due to the increasing electrification of production processes. Expanding renewable energy sources and networks is therefore a key prerequisite for achieving greenhouse gas neutrality in industry. According to the Federal Government's plans, almost all electricity shall come from renewable energy sources by 2035.

- **Increasing energy efficiency:** A further improvement in energy efficiency is essential to counteract the increasing demand for electricity.

- **Hydrogen:** Considerable greenhouse gas savings can be achieved in some sectors through using hydrogen. This is especially true for hydrogen-based steel production, where hydrogen is used instead of coal for directly reducing iron ore. Hydrogen also plays an important role in decarbonising the chemical industry.

- **CCU / CCS:** Carbon capture and storage (CCS) and carbon capture and use (CCU) technologies can be used to capture and store carbon dioxide or to use it further. This is particularly relevant for industrial processes where no climate-neutral key technologies are currently available, such as in the cement industry.

The Federal Government has launched extensive programmes to support the transformation of industry. Investments in existing high-efficiency technologies and renewable energy systems are promoted through the central support programme entitled "Energy efficiency and process heat from renewable energy sources in the economy". In addition to individual in-

vestments, the programme also promotes the energy- and resource-related optimisation of entire processes and production facilities. In order to largely reduce process-related greenhouse gas emissions, which are difficult to prevent according to the current state of technology, the Federal Ministry for Economic Affairs and Climate Action (BMWK) has set up the "Decarbonisation in Industry" support programme. This supports projects that help prevent process emissions in energy-intensive industries with the aid of innovative

-36 %

Emissions from the industrial sector decreased by 36 per cent between 1990 and 2021.

i

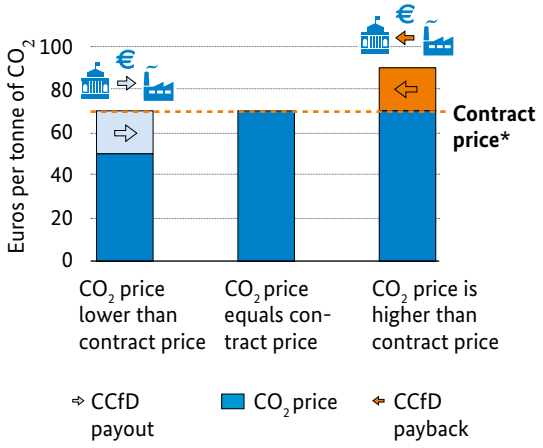
Carbon Contracts for Difference (CCfD)

Climate-friendly production processes often incur greater investment and operating costs than emission-intensive conventional production. Climate-friendly commodities are therefore not yet competitive compared with conventionally produced goods. CCfD can compensate for the additional costs of climate-friendly production and thus support industry transformation.

The Federal Government would like to test out this new and promising support instrument. Conventional CCfD guarantee a fixed CO_2 price (contract price). The contract price is agreed between companies and the public sector on a project-specific basis. The amount of the contract price is determined, among other things, by the abatement costs resulting from the prevented emissions and the additional costs incurred in converting production from a reference technology to a climate-friendly system. CCfD would oblige the public sector to pay out the difference between the CO_2 price for emission allowances in the EU ETS and the abatement costs (contract price) should the CO_2 market price lie below the contract price and thus the abatement costs. Conversely, companies could also be obliged to pay back their profits to the state if the market price exceeds the contract price.

By covering the abatement costs of climate-friendly technologies, CCfD can facilitate the competitiveness of low-CO_2 technologies. In the long term, CCfD can therefore support the market entry of climate-friendly technologies and prepare the development of green lead markets.

Figure 20: **Possible implementation of Carbon Contracts for Difference (CCfD)**



*Strike price agreed between the state and an investor for a specified period of time

Sources: Agora Energiewende (2022a), BMUV (2021a), BMWK (2020a)

climate action technologies. In addition, the BMWK plans to introduce CCfD (see info box on previous page). These are intended to cover the higher operating costs that arise from using innovative climate-friendly technologies compared with current emission-intensive technologies. As part of the Important Project of Common European Interest (IPCEI) state aid instrument, the BMWK and the Federal Ministry for Digital and Transport (BMDV) are also promoting the ramp-up of the entire hydrogen value chain (see also Section 4.3). Supported projects include, for example, industrial applications in the steel and chemical industries and in the production of electrolysers.

The European Commission is planning to realign European industrial policy with the European Green Deal and the proposals from the Fit for 55 package. This includes reforming the EU ETS and adapting it to the EU's new ambitious 2030 target. The reform proposal would, among other things, reduce the available emission allowances and thus increase the incentive to switch to low-emission production processes. In future, the competitiveness of European industry is to be additionally ensured by a Carbon Border Adjustment Mechanism (CBAM). This is intended to gradually replace the existing system that freely allocates emission allowances in the sectors concerned.

118 million t

By 2030, greenhouse gas emissions in the industrial sector are to be reduced to 118 million tonnes CO_2 equivalents.

3.4 Transport

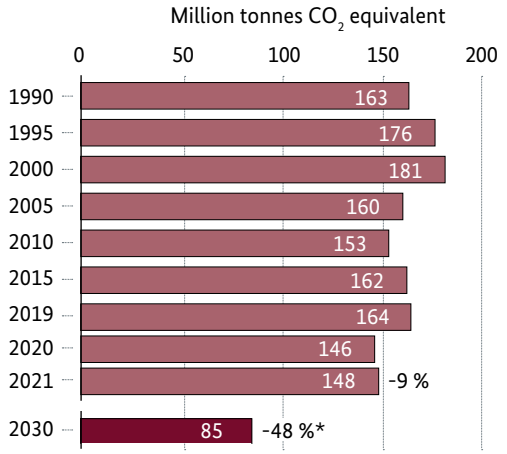
Emission trends

In 2021, the transport sector emitted greenhouse gases equivalent to 148 million tonnes CO_2 equivalent, which corresponds to 19 per cent of total emissions. That equates to a nine per cent decrease in emissions compared with the 1990 base year (Figure 21). In 2021, sector emissions therefore exceeded the permitted annual emission volume prescribed by the Climate Change Act by three million tonnes CO_2 equivalent, despite the partial reduction in transport traffic due to the pandemic. In order to achieve the 2030 sector target, this requires a reduction to 85 million tonnes CO_2 equivalent, which is equivalent to about minus 43 per cent compared with 2021.

In the past two years, emissions from the transport sector have been significantly lower, reducing by 11 per cent and 18 million tonnes CO_2 equivalent in 2020 compared with the previous year. Much of the decline is due to reduced mobility in the wake of the COVID-19 pandemic. Nationwide mobility, as measured by mobile phone data, had fallen by as much as 54 per cent during spring 2020 compared with the average for the respective months from 2019. A similar but less drastic effect was triggered by the second wave of infection, which significantly reduced mobility in winter 2020 and spring 2021 compared with the average from 2019. Only a small reduction in mobility amounting to -0.5 per cent was observed during the rest of the year, from May to December 2021, compared with the same period in 2019.[41]

At 97 per cent, motorised road traffic was again clearly responsible for the largest share of transport emissions in 2020. Passenger cars, heavy goods vehicles (HGVs) and other commercial vehicles respectively accounted for 59 per cent and 38 per cent of this amount (Figure 22). International shipping and aviation are not included in national transport-related greenhouse gas emissions. Emissions from electricity consumption in the transport sector (such as in rail transport) are also not included here. These are attributed to the energy sector according to the source principle. The dominance of fossil fuels also becomes clear when viewing the final energy consumption. Although the proportion of mineral oils used in transport is declining, it still accounted for by far the largest share in 2020 at 92 per cent (Figure 23).

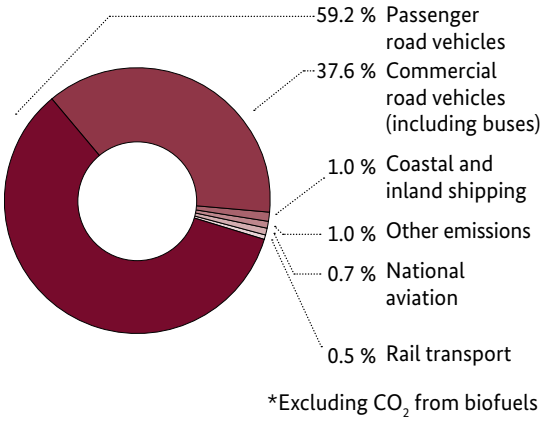
Figure 21: **Emission trends in the transport sector**



*Reduction target compared with 1990

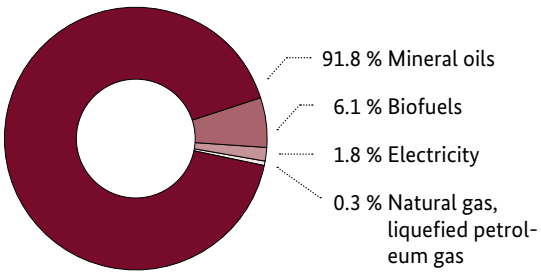
Sources: Federal Government (2021c), UBA (2022c)

Figure 22: **Sources of emissions in transport* (2020)**



Source: UBA (2022c)

Figure 23: **Final energy consumption by energy source in the transport sector (2020)**



Source: BMWK (2022a)

The share of motorised private transport in national passenger kilometres remains very high at 74 per cent. After decades of continuous growth, motorised private transport still accounts for a large proportion of passenger transport despite the measures taken so far. Rail and public road passenger transport only accounted together for 14 per cent in 2019, while cycling and walking each accounted for about three per cent (Figure 24).

In domestic German road freight transport, which mainly includes trucks, lorries and articulated lorries, transport volumes have doubled in the last three decades. Overall, freight transport increased by 68 per cent during this period, amounting to 673 tonne-kilometres. In freight transport, the tonne-kilometre unit describes the product of transported mass in tonnes and distance travelled in kilometres. Although rail freight transport has increased by 45 per cent since 2000, its relative share of total freight transport has stagnated at less than 20 per cent during the period under review. The freight transported by inland shipping is declining and has fallen by 32 per cent since 2000. A very small share of the total freight transport is accounted for by domestic air transport, which amounted to two billion tonne-kilometres in 2020 (Figure 25).

The effects of the COVID-19 pandemic are reflected in both passenger and freight transport. In both sectors there has been a significant decrease in total traffic compared with 2019. In 2021, mobility was less restricted than in 2020, which is why the total traffic for 2021 is expected to have increased again. Data on this is not yet available.

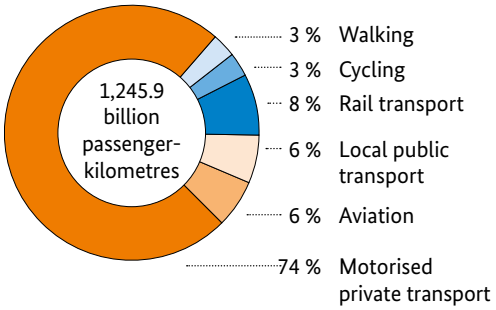
Areas of action and measures

There needs to be a further 43 per cent reduction in transport emissions in order to achieve the sector target by 2030. To this end, the Federal Government is introducing CO_2 pricing, promoting rail and local public transport, building new cycle paths and supporting electromobility as a key measure in the passenger car sector, which accounts for the majority of transport emissions.

CO_2 pricing in the transport sector is intended to create incentives for using climate-friendly alternatives. The pricing is determined through national emissions trading, which was extended to the transport and buildings

sectors in 2021. The fixed price of the emitted CO_2 will be successively increased. In 2021, the CO_2 price was equivalent to 7 cents per litre of petrol and 8 cents per litre of diesel.[42]

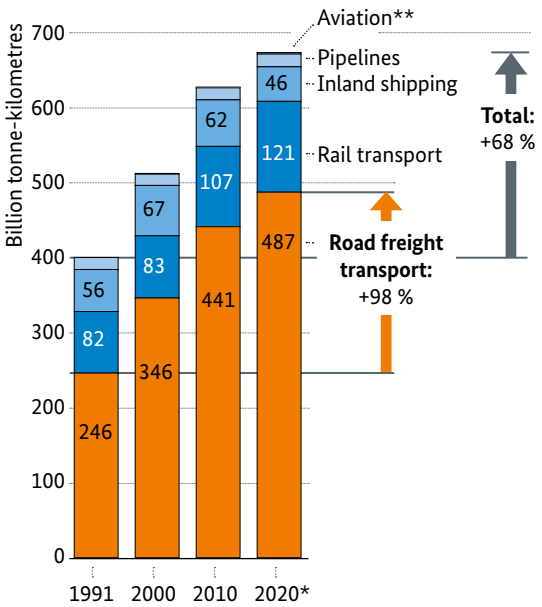
Figure 24: **Share of passenger transport by transport modes (2019)**



Shares as percentage values of passenger-kilometres

Source: BMDV (2022)

Figure 25: **Freight transport by transport modes**



*Estimate

**In 2020, freight transport in aviation amounted to two billion tonne-kilometres.

Source: BMDV (2022)

At the same time, climate-friendly alternatives to motorised private transport are being actively expanded. As part of the coalition agreement, the Federal Government has announced that it will continue to develop the Rail Transport Master Plan and implement it more quickly. Rail freight transport is set to increase to 25 per cent of freight transport by 2030.

Rail passenger transport is to be doubled by 2030. In addition, it is intended that 75 per cent of the rail network will use electric and innovative drive technologies by then. The expansion and modernisation of cycling as well as structural support for walking are also provided for in the coalition agreement.

In 2021, electric vehicles accounted for 26.1 per cent of new passenger car registrations. Their share has thus doubled compared with the previous year. A sharp increase has been observed since the middle of 2020, which can be explained by the use of environmental and innovation bonuses to subsidise passenger car models with electric drives, but also more generally by the stricter CO_2 fleet limits for new vehicles that apply throughout the EU. With the introduction of the innovation bonus in July 2020, the Federal Government doubled its previous support for alternative drive systems. Moreover, the total number of new passenger car registrations has fallen significantly in the last two years as a result of the pandemic and supply crisis (Figure 26). There was even a significant reduction in the total number of new registrations for vehicles with petrol and diesel engines compared with 2019.

The coalition agreement is aiming for at least 15 million fully electric passenger cars by 2030. This could increase the share of electric vehicles in passenger car transport to over 40 per cent, which, according to the forecast report, would close about half of the climate action gap by 2030. According to the European Commission's proposals, which are supported by Germany, from 2035 onwards only passenger cars and light commercial vehicles that do not emit any CO_2 emissions during operation should be allowed to be newly registered. In order to further support the market uptake of electric vehicles, the charging infrastructure master plan is also being revised. By 2030, one million publicly accessible charging points are set to be installed nationwide. The number of charging points totalled 55,843 at the beginning of 2022; 29,890 stations were reported in January 2020. The number of

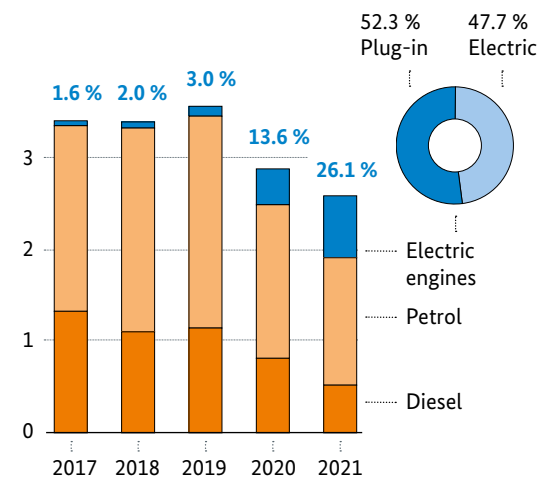
charging points has therefore almost doubled within the last two years.[43]

Power-to-liquid quotas in aviation and shipping are intended to stimulate the market ramp-up. From 2026, a minimum quota for power-to-liquid fuels of 0.5 per cent will apply to air transport. This will gradually increase to two per cent in 2030. Minimum quotas in shipping have not yet been enshrined in law, but are mentioned in the coalition agreement. The properties of power-to-liquid fuels are similar to those of conventional fuels. This has the advantage that they can be blended with other fuels, can be refuelled just as quickly, enable extensive ranges and can utilise existing infrastructures.

Power-to-liquid fuels are, however, significantly more energy inefficient compared with electric drives (Figure 27). This is not necessarily the case though in ecological terms. Ultimately, this depends on the users' demand structure and the regions for producing electricity or synthetic fuels. Battery electric mobility will, however, be able to exploit its energy advantages in the majority of applications.

Technological changes should also make road freight transport more climate-friendly. Here, too, electric drives are the main option. By 2030, they are intended to account for about one third of the mileage. The Federal Government is also supporting pilot trials to assess the practicality of HGVs powered by overhead lines as well as numerous projects using purely battery electric and fuel cell-powered HGVs, including in comparison with one another. The coalition agreement plans to differentiate HGV tolls according to their CO_2 emissions from 2023.

Figure 26: **New passenger cars registered from 2017 to 2021 in millions**



Source: KBA (2022)

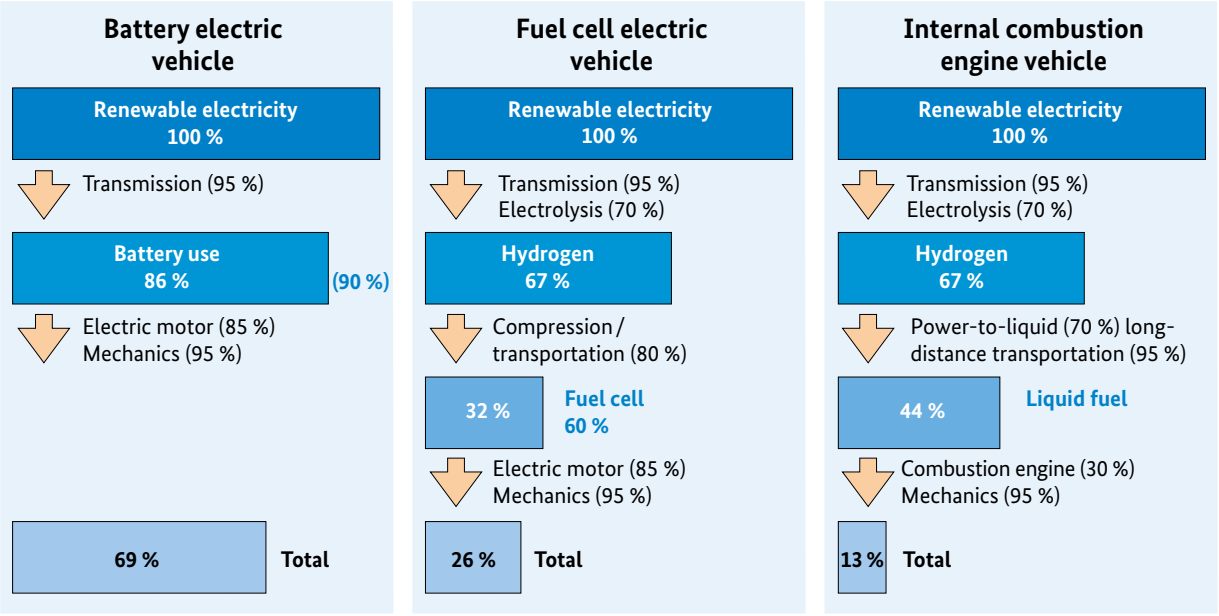
-9 %

In 2021, emissions from the transport sector were nine per cent below the 1990 level.

The Federal Government is also in favour of further developing the fleet limits and adopting an ambitious and feasible EURO 7 pollutant standard. A regulatory framework for successively decarbonising the transport sector is also taking effect at the European level. For example, car makers are subject to fleet limits for the average CO_2 emissions of their newly registered cars. Since 2021, the CO_2 emissions of new cars have to be reduced to 95 grammes of CO_2 per kilometre. Between 2025 and 2029, the current regulation stipulates a further reduction of 15 per cent and, from 2030, 37.5 per cent compared with 2021. However, this is currently being tightened up. The average value in 2018 was 130 grammes of CO_2 per kilometre in Germany and 120 grammes in the EU.[44] The fleet limits can be achieved by increasing efficiency and adding more electric vehicles to the fleet. Any companies that do not meet the targets will be liable for fines.

In accordance with the Climate Change Act, the BMDV submitted an immediate action programme on 13 July 2022 that proposed measures to compensate for exceeding the permissible annual emissions in the transport sector in 2021. The Federal Government will discuss this as a next step. Before the measures are adopted, the Expert Council on Climate Change will review the greenhouse gas reduction assumptions on which the measures are based. The measures contained in the sector-specific immediate action programme will later be integrated into the comprehensive and cross-sectoral Immediate Climate Action Programme.

Figure 27: **Individual and overall efficiency of passenger cars with different drive systems**



Note: Individual efficiencies shown in brackets. Multiplying the individual efficiencies gives the cumulative total efficiencies in the boxes.

Sources: Agora Energiewende (2018a), Agora Energiewende (2018b)

3.5 Buildings

Emission trends

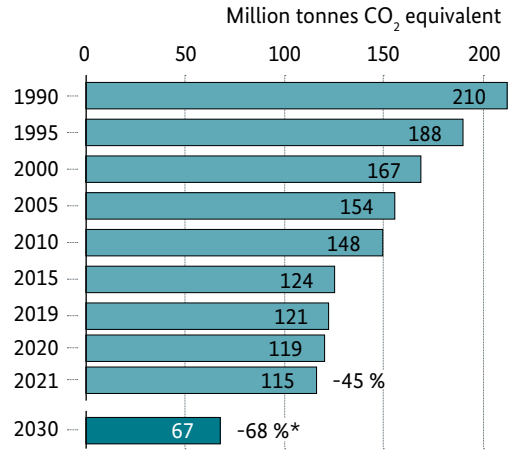
In 2021, the buildings sector accounted for 15 per cent of overall emissions in Germany. The sector includes greenhouse gas emissions from both private households and trade, commerce and services. Emissions from the sector fell by roughly three per cent between 2020 and 2021, to 115 million tonnes CO_2 equivalent. However, this can essentially be attributed to one-off effects caused by reduced heating oil purchases, as stocks were increased during previous years in anticipation of rising prices. Compared with the 1990 base year, overall emissions from the buildings sector were reduced by 45 per cent (Figure 28).

The buildings sector exceeded the projected emission levels in both 2020 and 2021. It has therefore not yet been possible to achieve the targets for the buildings sector set out in the Climate Change Act with the savings made so far. The target value for 2021 of 113 million tonnes CO_2 equivalent was missed by two million tonnes CO_2 equivalent.

A large proportion of the emissions in the buildings sector are caused by burning fossil fuels, especially natural gas. The provision of space heating and domestic hot water account for the largest shares of the energy consumed (Figures 29 and 30). According to the source principle, emissions caused by public supply companies delivering power and heat to the buildings sector (in particular for district heating) are attributed to the energy sector and referred to as indirect emissions.

As the weather influences energy consumption, it also influences emissions. More heating is needed at lower temperatures – and vice versa. This is particularly noticeable since the provision of space heating is responsible for about two thirds of greenhouse gas emissions in the buildings sector. Differing weather conditions mean that emissions from the buildings sector can fluctuate more strongly from year to year than in other sectors (see Section 3.1, Figure 11). Studies assume that the increase in warmer winters is actually one of the main reasons for the overall decline in emissions in the residential buildings sector.[45]

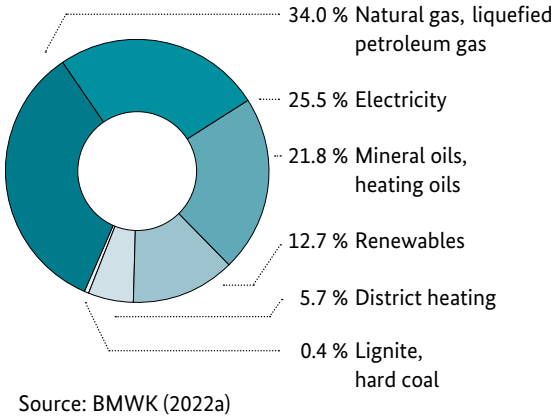
Figure 28: **Emission trends in the buildings sector**



*Reduction target compared with 1990

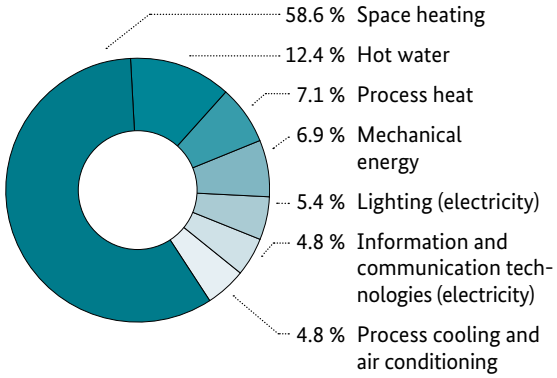
Sources: Federal Government (2021c), UBA (2022c)

Figure 29: **Final energy consumption by energy source in the buildings sector (2020)**



Source: BMWK (2022a)

Figure 30: **Final energy consumption by applications in the buildings sector (2020)**



Source: BMWK (2022a)

Areas of action and measures

Emissions from the buildings sector need to be reduced significantly more in order to achieve the climate targets. Limiting emissions to a maximum of 67 million tonnes CO_2 equivalent by 2030, as envisaged in the Climate Change Act, requires a significant increase in the reduction rate to about 44 per cent. Overall, the cumulative shortfall in achieving the 2030 climate target is estimated to be 152 million tonnes CO_2 equivalent from 2022 to 2030.[46] To close this shortfall, the energy efficiency of buildings and the expansion of renewable energy sources needs to be significantly increased. Among the important starting points for this is the switch to sustainable heating systems such as heat pumps, which are being increasingly used in the construction of new residential schemes (Figure 31).

Moreover, energy-efficient renovations are a key instrument for climate action and affordable housing. Saved heating costs can exceed a corresponding modernisation levy on the rent if ambitious renovations are carried out and subsidies are used.[47] In principle, it is intended that additional costs due to CO_2 pricing should be distributed between tenants and landlords based on the building's CO_2 emissions.

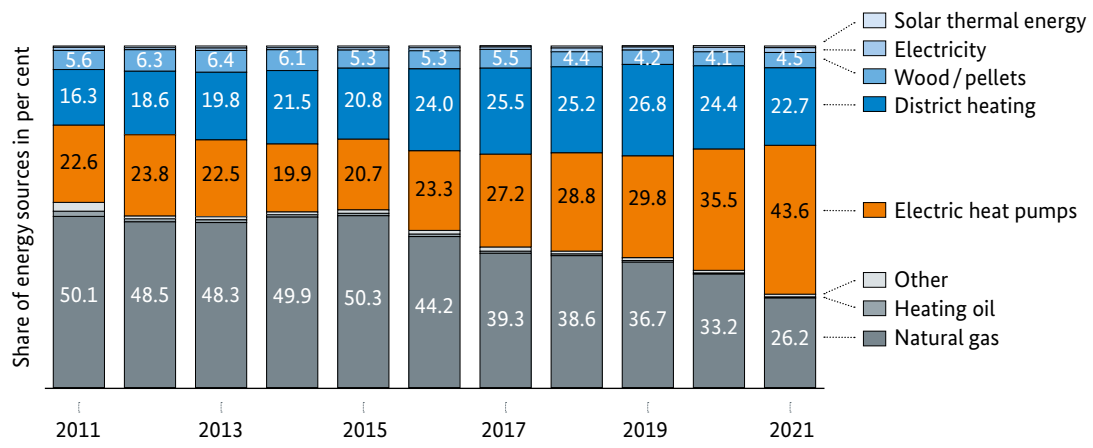
The EU aims to double the annual refurbishment rate with its renovation wave. To this end, the European Commission has launched an amendment to the Building Efficiency Directive as part of the Fit for 55 package to increase the requirements for new-build schemes and introduce minimum standards for existing buildings. These would be linked to the obligation to renovate those buildings that currently have the lowest efficiency classes within certain periods of time.

-45 %

Emissions from the building sector in 2021 were 45 per cent below the 1990 level.

In order to achieve the climate targets, the Federal Government is pushing ahead with revising the legal requirements and support measures. Among other things, the amendment to the Buildings Energy Act (Gebäudeenergiegesetz; GEG) is intended to implement the requirement that every newly installed heating system be based on at least 65 per cent renewable energy sources from the beginning of 2024. Overall, 50 per cent of heat is to be generated with renewable energy sources by 2030. In addition, the efficiency requirements for new buildings will be raised, initially with the introduction of the Effizienzhaus-55 standard. A further tightening is planned from 2025 with the Effizienzhaus-40 standard. The revised federal support for efficient buildings flanks the stricter requirements of the GEG. The support shall focus even more on the emission savings achieved. In particular, the entire life cycle shall be taken into greater consideration

Figure 31: **Share of heat pumps in new construction 2011 to 2021**



Source: BDEW (2022)

when subsidising new-build schemes. In addition, in response to the failure to meet the sector target, the Federal Government has provided more than five billion euros for energy-efficient renovations and the installation of energy-efficient heating systems with the immediate action programme 2022.[48]

On 13 July 2022, the Federal Ministry of Housing, Urban Development and Building (BMWSB) and the BMWK jointly presented an immediate action programme for the buildings sector. This proposes measures to bring the buildings sector on track in terms of climate policy so that the permissible annual emission levels can be met in future. As with the immediate action programme for the transport sector (see Section 3.4), the immediate action programme for the buildings sector will also be reviewed by the Council of Experts on Climate Change before the Federal Government adopts it as soon as possible. The measures in the immediate action programme for the buildings sector shall also be integrated into the comprehensive and cross-sectoral Immediate Climate Action Programme.

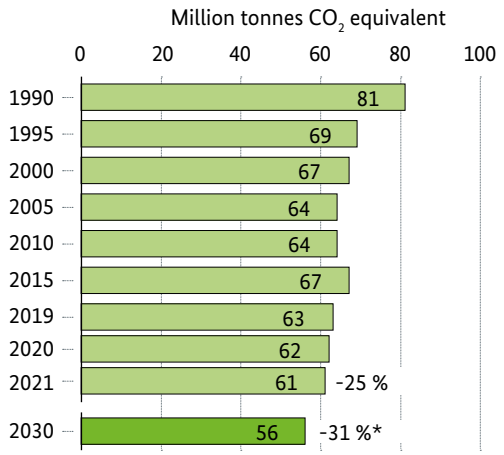
3.6 Agriculture

Emission trends

In 2021, the agricultural sector accounted for eight per cent of overall German emissions, at 61 million tonnes CO_2 equivalent. Compared with the previous year, agricultural emissions decreased by roughly two per cent. Relative to the 1990 base year, emissions in the sector have been reduced by 25 per cent. Between 2010 and 2021, greenhouse gas emissions declined slightly, reducing by around four per cent (Figure 32). In 2021, they thus remained significantly below the annual emission volume of 68 million tonnes CO_2 equivalents mandated in the Climate Change Act. However, this significant undercutting of the requirement is mainly due to methodological improvements in calculating the emissions that were not yet able to be taken into account in the targets. According to the forecast report, emissions from agriculture will exceed the target of 56 million tonnes CO_2 equivalent in 2030 by seven million tonnes CO_2 equivalent if no further measures are taken.[49]

The most significant decrease in emissions to date is primarily due to the decrease in livestock in the former Eastern Federal States immediately after reunification. Set-asides and improvements in fertiliser management also contributed. Livestock numbers continue to decline. Compared with 2020, cattle and pig populations recently decreased by 2.3 and 9.2 per cent respectively, resulting in less manure and fewer emissions. Digestion of ruminants accounted for most of the emissions in 2020, despite declining livestock numbers (Figure 33).

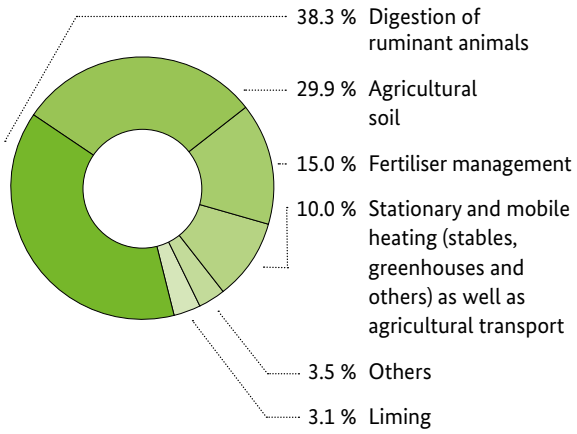
Figure 32: **Emission trends in the agricultural sector**



*Reduction target compared with 1990

Sources: Federal Government (2021c), UBA (2022c)

Figure 33: **Sources of emissions in agriculture* (2020)**



*Excluding CO_2 from biomass

Source: UBA (2022c)

-25 %

Emissions from the agricultural sector decreased by 25 per cent between 1990 and 2021.

The majority of emissions in agriculture occur in the form of methane and nitrous oxide (Figure 34). Methane is roughly 25 times more harmful to the climate than CO_2, while nitrous oxide is around 300 times more harmful. Methane is primarily released by digestive processes of ruminants, especially beef and dairy cattle, and when storing and spreading animal fertilisers such as liquid manure and solid dung.

Farming organic soils and using mineral fertilisers and organic fertiliser releases nitrous oxide. Emissions from the agricultural use of soils amounted to just under 30 per cent in 2020, while those from fertiliser management amounted to 15 per cent.

In contrast to other sectors, CO_2 plays a lesser part in greenhouse gas emissions in the agricultural sector (Figure 34). The sector causes around 65 per cent of all methane emissions and 77 per cent of nitrous oxide emissions in Germany.

Just over 60 per cent of emissions from agriculture are directly due to livestock farming.[50] It accounted for 5.1 per cent of German emissions in 2020. Most methane and nitrous oxide emissions from livestock farming can be attributed to dairy cows and other cattle (2019: 84 per cent, Figure 34). Pigs account for 10 per cent, while other livestock such as poultry, sheep, goats and horses account for only three per cent of these emissions. The respective shares according to the animal species have remained at a largely constant level over the years.

Areas of action and measures

In 2030, annual greenhouse gas emissions will be capped at 56 million tonnes CO_2 equivalent in accordance with the Climate Change Act. This corresponds to a 31 per cent reduction compared with 1990 and requires a reduction of 8 per cent compared with 2021. To achieve this, a sustainable transformation of agriculture and food is necessary that meets the needs of the environment, animals and the climate. According to the coalition agreement, Germany's agricultural sector is to be based on the principles of protecting the environment and conserving resources. Reducing livestock, taking animal welfare into account, therefore takes on key importance.

The area farmed organically relative to all farmed land is to be increased to 30 per cent by 2030 instead of the 20 per cent envisaged so far, which equates to an almost threefold increase from the current 10.3 per cent.[51] Organic farms emit less greenhouse gases than conventional farms of the same size, as they do not use mineral fertilisers, eliminating the greenhouse gas emissions caused by their manufacturing processes. Besides, the nutrient-rich humus content in organically farmed soils is often higher. The expansion of organic farming could benefit from reducing the consumption of animal products. Less livestock farming would make more land available for direct food production. In addition, the Federal Ministry of Food and Agriculture (BMEL) will present a strategy to ensure that the share of organic farming products on supermarket shelves is also increased to 30 per cent.[52]

The Federal Government plans to adopt a food strategy by 2023. As stated in the coalition agreement, the share of regional and organic products is to be increased in line with the expansion targets. In addition, the strategy aims to reduce food waste in a binding and sector-specific manner. The strengthening of plant-based alternatives should reduce the consumption of animal products. At the EU level, the Federal Government will therefore work to ensure that alternative protein sources and innovative meat substitutes are approved.

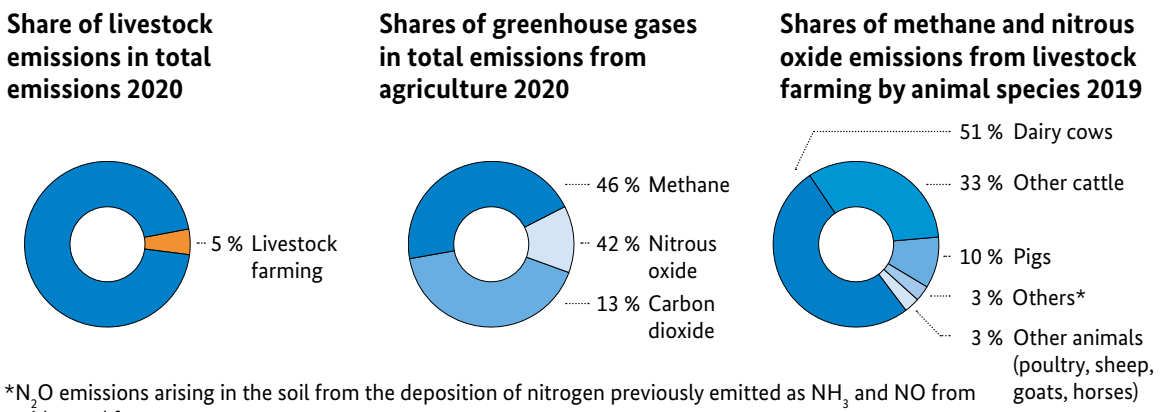
Agriculture is particularly affected by the consequences of climate change. Extreme drought, freak weather and seasonal shifts are examples of impacts

that particularly affect farmers. For example, the consequences of extreme drought became noticeable in 2018 and 2019. Besides harvest losses, there were also shortages in the supply of animal feed. Adapting to the consequences of climate change therefore plays a key role in the agriculture sector. For this reason, too, the Federal Government is planning to improve the framework for breeding climate-resistant plant varieties.

> ***"The forests are our natural air conditioning system. But the damage caused by storms, drought and bark beetles has truly burnt itself into the landscape. This forest damage shows us what the climate crisis means for us."*** *Cem Özdemir, Federal Minister of Food and Agriculture*

The EU's Common Agricultural Policy (CAP) has a major influence on mitigating climate change in the agricultural sector. The CAP Strategic Plan, which the BMEL submitted to the European Commission for approval in February 2022, sets support priorities, including in the interest of environmental protection and climate action. It supports resilient agricultural production to strengthen food security, rewards environmental conservation and climate action, and thus contributes to the sustainability of rural areas.

Figure 34: **Focus on emissions from livestock farming**



*N_2O emissions arising in the soil from the deposition of nitrogen previously emitted as NH_3 and NO from stables and farm manure stores

Sources: Thünen Institute (2021), UBA (2022d)

3.7 Waste and recycling management

Emission trends

The waste and recycling management sector has the smallest share of greenhouse gas emissions in Germany, at one per cent. In 2021, emissions from the sector amounted to eight million tonnes CO_2 equivalent (Figure 35). This corresponds to a decrease of four per cent compared with the previous year. Following 2020, 2021 marked another year in which the waste and recycling management sector remained below the annual emission volume of the nine million tonnes CO_2 equivalent prescribed in the Climate Change Act.

The largest climate-relevant source of emissions from the waste management sector comprises methane emissions from landfills. These are responsible for 77 per cent of the sector's greenhouse gas emissions. The remaining emissions stem from biologically treating solid waste and wastewater treatment, which account for 12 and 11 per cent respectively (Figure 36).

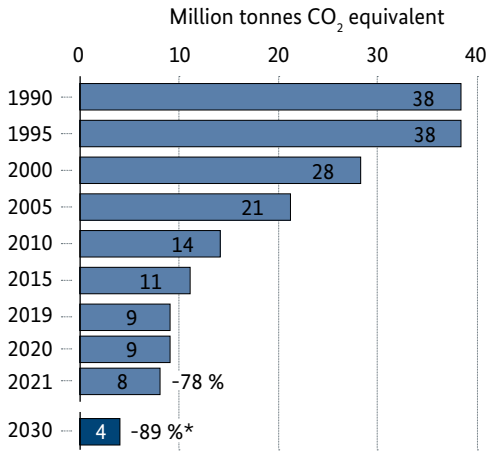
With 78 per cent, the waste and recycling management sector has achieved the highest reduction in emissions among the sectors since 1990. In 1990, the waste management sector still emitted 38 million tonnes CO_2 equivalent, causing three per cent of total emissions in Germany. By 1992, emissions in the sector had risen to roughly 40 million tonnes CO_2 equivalent. Since then they have fallen continuously, by an average of five per cent per year. Phasing out the disposal of untreated municipal waste in landfills and the increased use of waste for materials and energy make the greatest contribution to climate action in the waste management sector.

The volume of residual waste in Germany has been halved in the past 35 years. Municipal waste disposal paths (Figure 37) have changed decisively since 1990. Today, more recyclable materials are collected and recycled separately. Well over half of household waste – especially waste paper, waste glass, packaging and organic waste – is now recycled.[53] This conserves natural raw materials and mitigates climate change, because recycling requires less energy and resources than the extraction of new raw materials. Efficiently using the remaining residual waste to generate energy in power plants is another effective form of climate action, as it replaces fossil fuels as sources of energy. However, based on the source principle, these savings are credited to the industrial and energy sectors rather than the waste management sector.

-78 %

Emissions from waste and recycling management decreased by 78 per cent between 1990 and 2021.

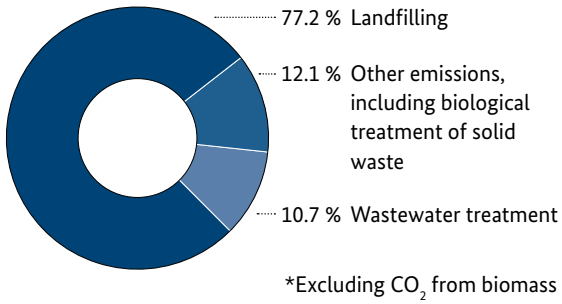
Figure 35: **Emission trends in waste and recycling management**



*Reduction target compared with 1990

Sources: Federal Government (2021c), UBA (2022c)

Figure 36: **Sources of emissions in waste management and recycling* (2020)**



*Excluding CO_2 from biomass

Source: UBA (2022c)

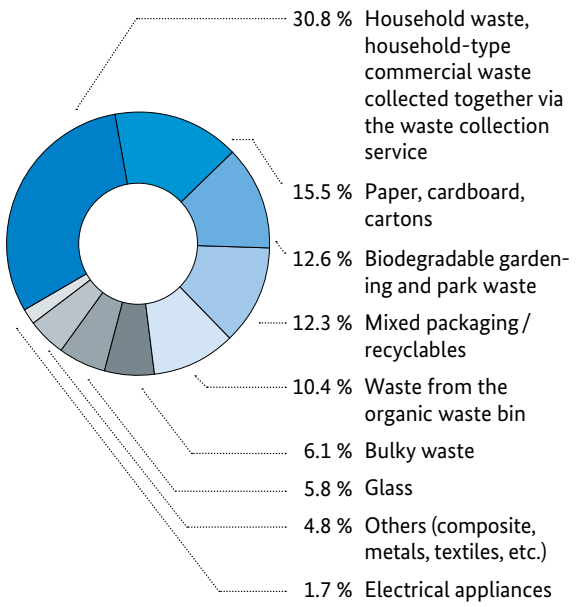
Reducing methane emissions from landfills makes the greatest contribution to climate action in the waste sector. In particular, banning the disposal of untreated organic municipal waste in landfills in 2005 has played a key role. Landfill companies that capture some of the landfill gas, predominately methane, and use it to generate energy, also make a contribution.

Areas of action and measures

The Climate Change Act prescribes that greenhouse gas emissions from the waste and recycling management sector should fall from 8.4 million tonnes CO_2 equivalent today to 4 million tonnes in 2030. This corresponds to a reduction of 52 per cent.

By expanding measures for ventilating landfills, optimising gas collection and reducing food waste, the sector's emissions can be significantly further reduced by 2030. The forecast report predicts, however, that based on current measures a shortfall of about one million tonnes CO_2 equivalent will still need to be closed in order to attain the sector target in 2030.[54] Further measures are therefore required, which are currently being prepared by the Federal Government.

Figure 37: **Composition of typical household municipal waste (2019)**



Source: UBA (2022e)

Existing raw materials policy strategies are to be bundled together in a national recycling management strategy. To this end, the Federal Government will adapt the existing legal framework, define clear targets and review waste legislation. In future, products should be durable, reusable, recyclable and, if possible, repairable. Based on the developed recycling management strategy, the Federal Government will also work to ensure uniform standards at EU level. This is because sensible, ambitious requirements for products need to be developed in dialogue with manufacturing companies and defined uniformly throughout Europe.

3.8 Land use, land use change and forestry (LULUCF)

Emission trends

Overall, the LULUCF sector acts as a sink for greenhouse gases in Germany. While specific land-use forms currently emit more greenhouse gases than they sequester and act as net sources, others provide more sequestration than emissions of greenhouse gases and thus act as net sinks. The sector's emission balance is calculated from the difference between released and sequestered greenhouse gases. In 2020, the LULUCF sector's emissions balance amounted to minus 11.3 million tonnes CO_2 equivalent (Figure 38) (2021: minus 11.5 million tonnes CO_2 equivalent).

For the Greenhouse Gas Inventory 2022, the UBA and the Thünen Institute have made back calculations. These are based on various methodological improvements and adjustments, and in some cases entail considerable changes in the source groups concerned. For example, the values for the LULUCF sector presented here include a revision of the emission factors for forest biomass. Among other things, this explains the differences between the emission balances reported this year and last year (-17 million tonnes in 2020 vs. -11 million tonnes in 2021). The forest damage caused during previous years has already been partially taken into account via logging statistics. A final verification will only be possible with the next federal forest inventory, which is due to be published in 2025 / 2026.

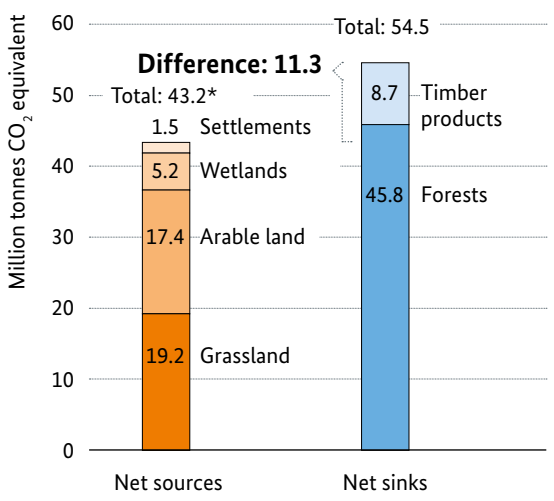
Currently, most land-use forms release more emissions than are sequestered by them. Carbon dioxide emissions arise, for example, from the agricultural use of soils, primarily on drained peatland sites and in deforestation. The largest sinks are forests (Figure 38). In 2019, the forest ecosystem stored a total of 3.1 billion tonnes of carbon throughout Germany.[55] Due to forest management that is one-sidedly oriented towards extracting timber, as well as a lack of climate adaptation, German forests have already lost parts of their sink capacity.

The storm- and drought-related damage to German forests since 2018 could also be exacerbating these effects. The severe storms that occurred in autumn 2017 and spring 2018, as well as the dry years from 2018 to 2020, contributed to the mass proliferation of insect pests such as the bark beetle, causing considerable damage to forests. This is also reflected in the comparatively extensive logging in 2020 and 2021, which, compared with 2006, increased by 33 per cent in 2021. This is due to forced use, i.e. unplanned use due to damages caused by increased insect infestation, wind and storms. The proportion of damaged timber in 2021 was around 61 per cent or 50.5 million cubic metres. It is particularly noticeable that the proportion of damaged timber caused by insects has increased sharply in the past three years compared with before (Figure 40). According to the forest condition survey conducted by the BMEL, 80 per cent of all trees in Germany show symptoms of damage.[56] Satellite-based earth observation data from the German Aerospace Center (DLR) shows that the number of trees lost in Germany between January 2018 and April 2021 covered an area equivalent to 501,000 hectares, which corresponds to almost five per cent of the total forest area.[57] This highlights the particular importance of ecologically restructuring forests and protecting them from the increasing impacts of climate change.

-11.3 million t

In 2020, the emissions balance of the LULUCF sector was minus 11.3 million tonnes CO_2 equivalents.

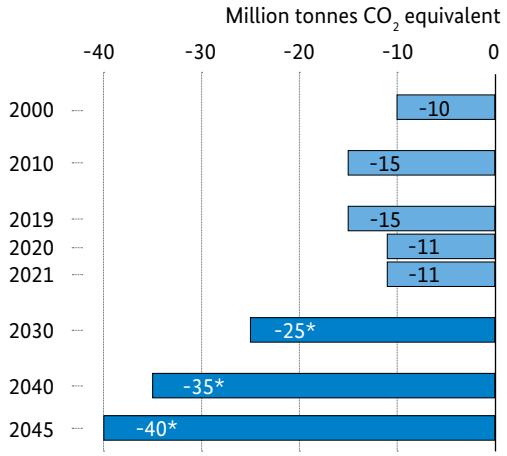
Figure 38: **Emission sources and sinks LULUCF (2020)**



*Slight difference in totals due to rounding error

Source: UBA (2022c)

Figure 39: **Emission trends in LULUCF**



*Targets according to the Climate Change Act for the mean value of the of the respective target year and the three preceding years.

The values shown are the difference between emission sources and sinks in the LULUCF sector.

Sources: Federal Government (2021c), UBA (2022c)

Areas of action and measures

The amendment of the Climate Change Act set binding targets for the LULUCF sector for the first time. The sector's contribution is essential for achieving greenhouse gas neutrality from 2045. Accordingly, the sink function is to be increased to at least 25 million tonnes CO_2 equivalent by 2030. In 2040, this should be at least 35 million tonnes CO_2 equivalent, and 40 million tonnes in 2045 (Figure 39). Thus, in addition to species conservation, the preservation of peatlands and forests through nature-based solutions for climate and biodiversity forms the focal point of the strategic cooperation between the Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) and the BMEL.

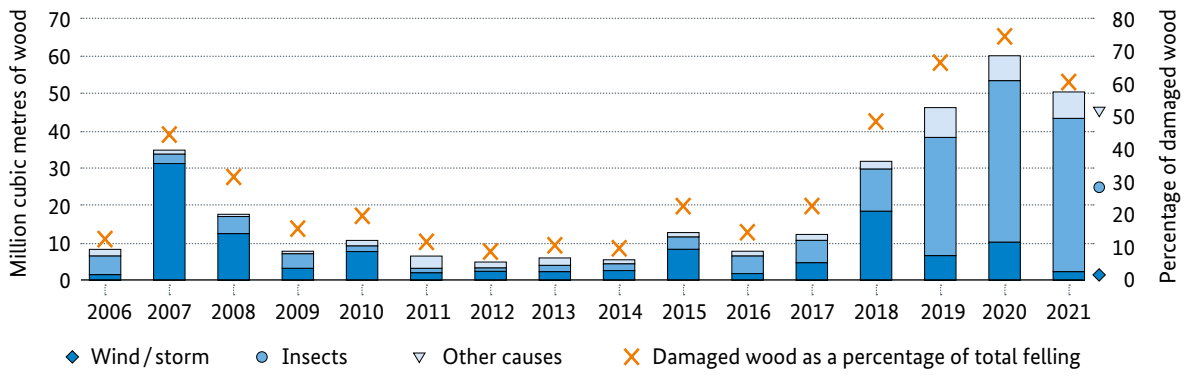
The Federal Action Plan on Nature-based Solutions for Climate and Biodiversity (ANK) will contribute to protecting and restoring ecosystems. The BMUV's ANK plan utilises synergies between climate action and nature conservation in a targeted manner. Four billion euros will be made available for this purpose between 2022 and 2026. The resilience of ecosystems will be strengthened through renaturation and restoration measures. In Germany, 92 per cent of peatland soils are currently drained, causing emissions of around 53 million tonnes CO_2 equivalent every year. A national peatland conservation strategy and the Climate Action Through Peatland Conservation federal programme are intended to promote the re-wetting of drained peatlands and thus reduce greenhouse gas emissions. The ANK plan also focuses on the protection of forests, soils, water bodies, floodplains and grasslands, as well as marine and coastal ecosystems.

Targeted forest restructuring is aimed at creating species-rich and climate-resilient forests. To this end, the National Forest Act is to be amended and the Forest Damage Compensation Act will be evaluated. In addition, the intervals and form of the federal forest inventory are to be reviewed and digital forest monitoring will be introduced.

The Federal Government's other plans include establishing a soil monitoring centre and a federal nature conservation fund.

The LULUCF sector is expected to make an important contribution to achieving the EU's target of reducing its greenhouse gas emissions by 55 per cent by 2030. The European Commission has therefore proposed that the EU's LULUCF Regulation should be adapted as part of the Fit for 55 package. The aim of the proposal is to achieve an EU-wide net carbon sink of at least 310 million tonnes CO_2 equivalent by 2030. Each EU Member State would be responsible for a share that is bindingly set as a national target. This target would be divided among the Member States according to the average emissions data reported between 2016 and 2018 as well as the land area under cultivation. The change will not apply to the first commitment period, but only from 2026. From 2031, the LULUCF and agricultural sectors would be considered together and become climate neutral in the balance by 2035.[58] The decision on the proposal is still pending.

Figure 40: **Tree felling due to damage**



Sources: Destatis (2022a), Destatis (2022b)

4. The path to greenhouse gas neutrality as an economic and social opportunity

Summary

Spotlight: The ambitious goal of becoming greenhouse gas neutral by 2045 can be achieved. Five major current studies describe potential solution spaces on the path to greenhouse gas neutrality.

The transformation towards greenhouse gas neutrality offers substantial **opportunities for the competitiveness of the German economy**. To make climate action – but also social participation – a more consistent feature of economic policy, the social market economy is being developed into an ecological social market economy.

On the path to greenhouse gas neutrality, there will be additional demand for jobs, leading to numerous **new employment prospects**. In regions where jobs are being lost, the Federal Government is supporting regional partnership projects, among other things, to promote innovation and job creation.

Sustainable infrastructures are the backbone of a greenhouse gas neutral economy and society. To speed up the necessary modification and expansion of infrastructures, planning and approval procedures are being modernised. As a result, the transmission and distribution grids as well as the heat supply infrastructure will be transformed more quickly.

Sustainable investments also play a key role in achieving the climate targets. National and global financial flows must be brought into line with the goal of greenhouse gas neutrality. Germany is to become the leading location for sustainable finance. Subsidies and spending that harm the environment and climate will be systematically eliminated.

IN FOCUS 2022: Possible future developments on the path to greenhouse gas neutrality – overview of transformation scenarios

Five recently published major studies show that Germany can achieve net greenhouse gas neutrality by 2045.[59] Based on various scenarios, the studies describe possible CO_2 reduction paths representing solution spaces for achieving greenhouse gas neutrality.

The solution paths share similar basic features, but differ in the detail. For example, all scenarios assume that greenhouse gas emissions will be cut rapidly – down by 65 per cent by 2030 compared with 1990. The 2030 sector target for the energy industry is also met or even exceeded in all scenarios. The majority of the remaining greenhouse gas emissions in 2045, which must be offset by negative emissions, will be attributable to the agricultural sector. With one exception, the studies assume a decrease in final energy consumption of around 45 per cent by 2045. Regarding the amount of "power-to-X" in final energy consumption in 2045, for example, the studies arrive at different projections ranging from 4 to 25 per cent.

In all scenarios, electricity plays a key role in the transformation towards a greenhouse gas neutral economy and society by 2045. Firstly, the energy industry produces the most greenhouse gas emissions of all sectors in Germany. Secondly, electricity is the most important energy source needed to decarbonise other sectors. The studies are in agreement that energy consumption is expected to increase from 600 terawatt hours today to around 1,000 terawatt hours in 2045. To meet growing electricity consumption in a climate-neutral way, renewable generating capacity will have to nearly quadruple by 2045. Accordingly, the Federal Government's Easter Package of energy policy measures focuses on accelerated and greatly increased expansion.

The growing demand for electricity generated from renewable energy sources is primarily due to the direct electrification of the consumption sectors. Renewable electricity will be used as a central energy source in sectors that currently mainly use fossil fuels. For example, the transport sector is to be almost completely electrified by 2045. Industrial heat generation, which today relies almost exclusively on coal and natural gas, will largely switch to renewable electricity by 2045. In the scenarios, heat generation in homes is also electrified. By 2045, mainly heat pumps will be used in the installation of new heating systems. Thus the studies predict that five to six million heat pumps will be in operation by 2030.[60]

Renewable electricity will also be needed to produce green hydrogen, which is obtained by water electrolysis using renewable electricity. According to the studies, green hydrogen production will account for about 150 terawatt hours of gross electricity consumption in 2045.[61] While electrolysis capacity in Germany will have to be expanded for this purpose, most of the demand for green hydrogen will be imported from countries that have more space available and better conditions for renewable energy generation.

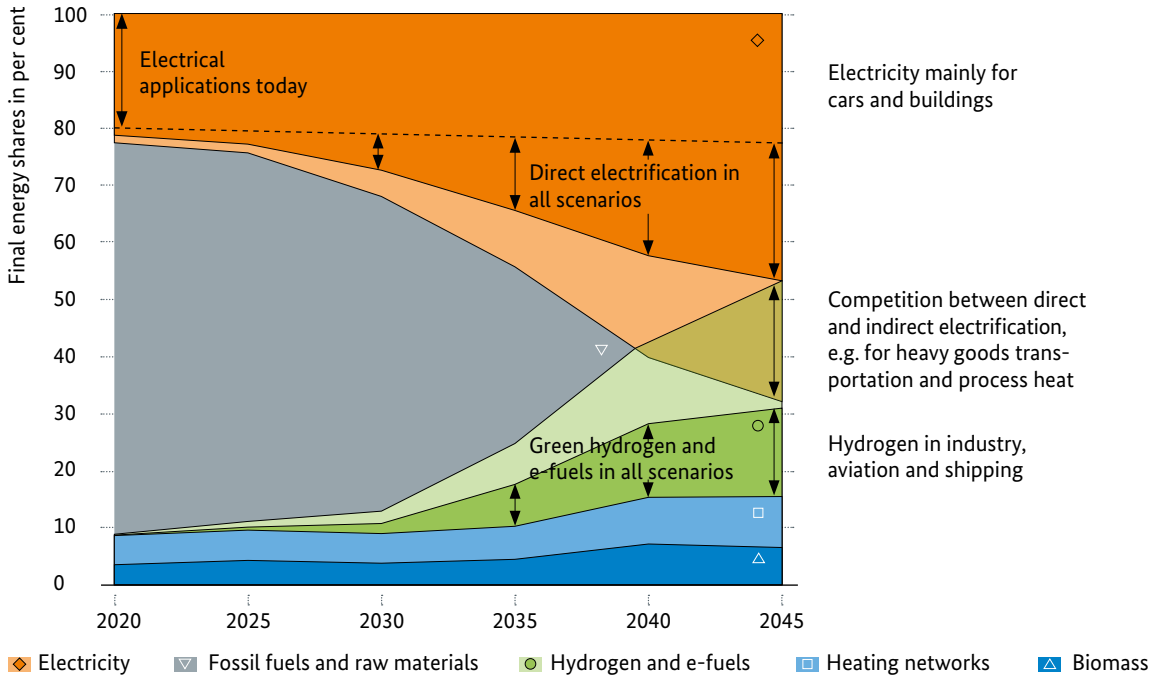
Hydrogen is mostly needed for the transformation of industrial processes such as the production of ammonia, methanol and steel. In steel production, for example, direct reduction plants are expected to replace CO_2-intensive blast furnaces. In the long term, this change will require the use of hydrogen instead of coke and coal as reducing agents. Green hydrogen will also be used particularly for flexible electricity production and also for the generation of high-temperature heat.

Furthermore, other synthetic energy sources (e-fuels) are to be used. The main need for e-fuels is in sectors where direct electrification is not possible, for example in shipping and aviation (see Figure 41).

To achieve the necessary market ramp-up of green hydrogen, the Federal Government has doubled the expansion target for electrolysers to 10 gigawatts by 2030. To achieve this goal, the Federal Government intends to financially support investments in hydrogen technologies through additional support programmes and CCfD.

In all five scenarios, climate neutrality is achieved through the additional use of technical CO_2 sinks to offset remaining emissions.[62] These include capturing biogenic emissions when biomass is used as fuel (bioenergy with carbon capture and storage; BECCS) as well as direct capture and storage of CO_2 from the atmosphere (direct air carbon capture and storage;

Figure 41: **Final energy shares in different decarbonisation scenarios**



Source: Ariadne-Projekt (2021a)

DACCS) or its use in durable products (direct air carbon capture, utilisation and storage; DACCUS). Using these technologies requires additional resources, land, infrastructure and energy. They are a supplement but not an alternative to the avoidance of emissions across all sectors. Unless emission avoidance is prioritised, the climate targets cannot be achieved. Further research and development is needed before these technologies can be deployed at scale, which will then allow their actual climate contribution to be assessed.

Figure 41 shows the described developments based on shares in final energy consumption. Electrification of passenger cars and the heat supply would increase the share of direct electrification (orange) in final energy consumption to at least 47 per cent by 2045. Indirect electrification (green) occurs primarily through the use of hydrogen and e-fuels in sectors that cannot be directly electrified, such as industry (primary steel and basic chemicals), aviation and shipping. The paler areas represent the range of possible direct and indirect electrification. It can be seen that for some applications, such as heavy goods vehicle traffic or process heat, it is not yet clear whether electricity or hydrogen will prevail. The final energy mix also includes the heat supply, which will make up 15 per cent of final energy consumption by 2045, with growth in bioenergy and the expansion of heating networks.

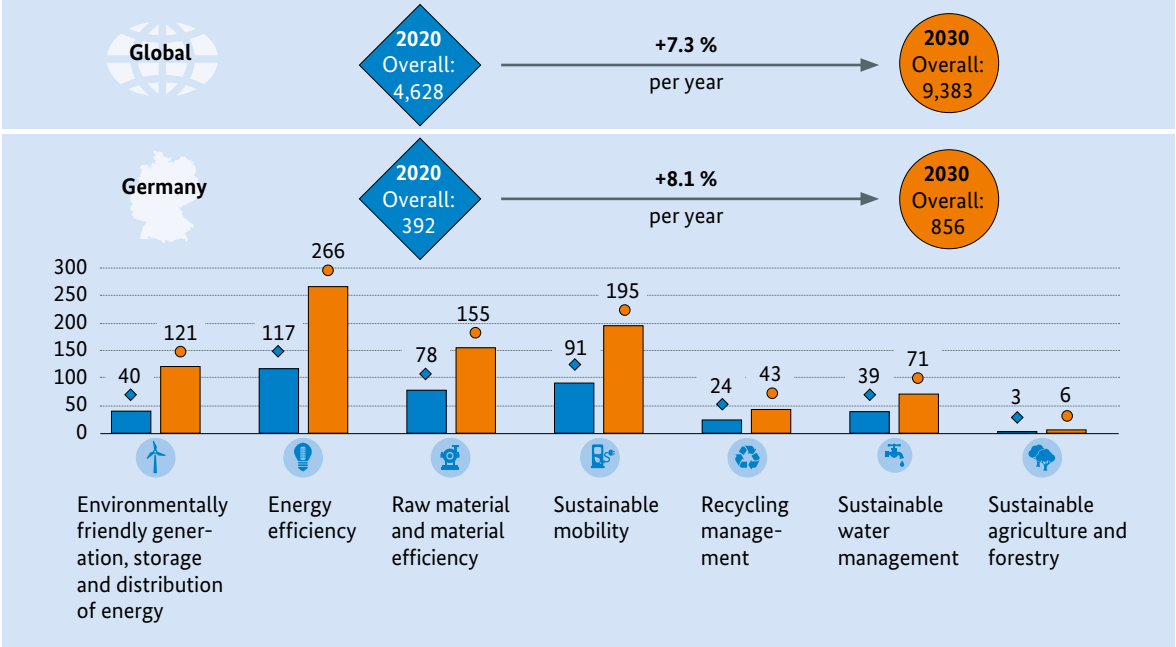
4.1 Transformation into an ecological social market economy

The transformation towards greenhouse gas neutrality offers substantial medium and long-term opportunities to reshape economic activity and the competitive landscape. The long-term economic cost of inaction far exceeds the investments needed to restructure the German economy. So a rethink is essential. To make climate action – but also social participation – a more consistent feature of economic policy, the social market economy is being developed into an ecological social market economy. The link between the "environmental" and the "social" can be found in the key question of how social participation can be re-established in the transformation. Economic policies should be designed with the environment in mind, but they should also be socially balanced and socially acceptable. Climate policy can play an active role here. By increasing competitiveness, it creates new jobs in climate-relevant sectors while also ensuring greater prosperity though higher investment in environmental and climate technologies (see Sections 4.2 and 4.5).

The thematic link between the economy and the environment is also reflected in the newly restructured BMWK. Its Annual Economic Report 2022 focuses not only on growth, but also on climate action, sustainability, resource conservation and social aspects. For the first time, supplementary well-being and sustainability indicators beyond gross domestic product have been considered, and prosperity defined in terms of socio-economic aspects. The interests of future generations and the protection of global environmental goods are also taken into account. In recent years, many businesses have begun to change their consumption and production processes accordingly.

Climate action policy can ensure prosperity in Germany by creating new, sustainable value chains and future markets. Environment and climate technologies (green tech) are already an important cornerstone of the German economy. Green tech markets will continue to grow in importance in the future. The climate neutrality targets of many nations, together with overarching policy strategies like the European Green Deal, provide the framework for this growth. The global green tech market is forecast to grow by 7.3 per cent annually until 2030. With a projected annual growth

Figure 42: **Forecast for the global and national market volume trends for environmental technology and resource efficiency 2020 to 2030 (in billion euros)**



Source: BMUV (2021b)

rate of 8.1 per cent, the German market is expected to grow even faster, reaching a volume of 856 billion euros by 2030 (see Figure 42).

Green tech "made in Germany" has a good reputation worldwide, explaining the German sector's strong export position. While Germany accounts for roughly three per cent of global economic output, German companies have a 14 per cent share of the global market for environmental technology and resource efficiency. In the coming years, work must be done to maintain these good market positions, face up to growing competition – especially from China and the United States – and become a role model for the green transformation in Europe.[63]

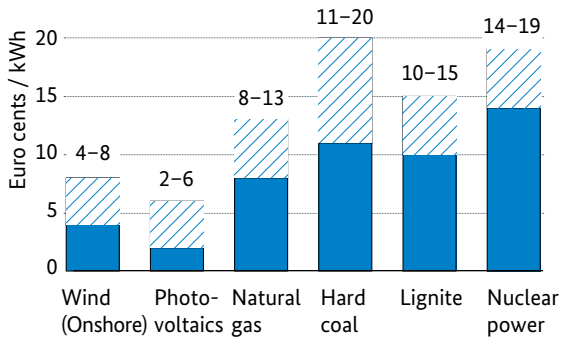
The Federal Government will support the transformation process in the German automotive industry, against a background of digitalisation and decarbonisation. It will align framework conditions and support measures to help Germany become the lead market for electromobility, with at least 15 million electric cars in 2030.

Electricity generation costs from new renewable energy plants are already lower than from conventional power plants in many cases (see Figure 43). At four to five euro cents per kilowatt hour, the price level of electricity from new solar and wind farms is half of the average exchange electricity prices in 2021 on the German day-ahead market.[64] Germany's electricity supply remains very reliable even as the share of renewable energy grows. A new record for the lowest ever power supply outage time was achieved in 2020, breaking the previous record set in 2019.[65] At the same time, the energy and gas price crisis in the winter of 2021 / 22 and, even more so, Russia's war of aggression against Ukraine clearly illustrate the disadvantages of dependence on fossil fuels, the vast majority of which have to be imported. For sustainably thinking companies, the share of renewables is increasingly becoming a locational advantage.

We think about economic policy in social and environmental terms. Negative effects of climate policy will be compensated. A social compensation mechanism referred to as the "climate premium" ("Klimageld") is intended to redistribute revenues from CO_2 pricing in the heating and transport sectors to citizens as a way of compensating them for future increases in the CO_2 price and fostering acceptance of the market system. The climate premium is to be paid out to citizens via their tax ID number. This was decided by the Federal Government in early 2022 in the context of the packages of measures to deal with high energy costs in the short term, which are not related to the CO_2 price. An already tense situation on the energy markets was made significantly worse by Russia's attack on Ukraine. The relief packages agreed by the Federal Government in response include the complete abolition of the shared contributions under the Renewable Energy Sources Act (the EEG levy), an increase in the long-distance commuter allowance, a one-time energy allowance, a one-off payment of 200 euros for people receiving social benefits, concessions for local public transport and temporary tax reductions (including on petrol and diesel). In addition, low-income households will receive a one-time heating cost allowance in 2022.

These short-term relief measures do not constitute compensation for additional burdens due to climate policy, but they cannot be viewed as completely unrelated to it, either. The Federal Government considers the shaping of a socially just climate policy – for example with the climate premium – to be one of its ongoing core tasks, along with promoting acceptance, participation and ownership of climate action.

Figure 43: **Electricity generation costs in the EU with new large power plants**

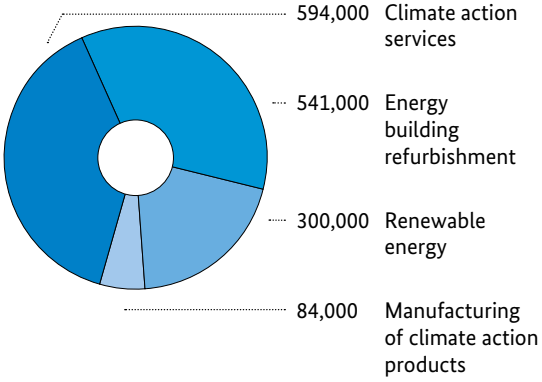


Source: BMWK (2022c)

4.2 Jobs and structural change

Of the 45 million people employed in Germany, 1.5 million worked in climate action in 2019. Of these, 594,000 people were employed in the climate action services sector. Employers include corporate service providers like architects or engineers who design renewable energy systems. The renewable energy sector employed 300,000 people. A further 84,000 jobs were provided by manufacturers of climate action goods. They include providers of mechanical engineering including repairs, rubber and plastic goods, data processing, chemicals, glass and glass goods, as well as metal products. Employment in the energy building refurbishment sector totalled 541,000 (see Figure 44).

Figure 44: **Jobs in climate action (2019)**



Source: UBA (2022f)

Climate and environmental action will create many more jobs in Germany in the future. A study by the Institute for Employment Research (IAB) on the effects of the new climate action and social housing targets and measures in the coalition agreement forecasts that from 2025 onwards, around 400,000 additional workers will be needed in these areas. In parallel, according to the study, there will be an increase in the labour supply due to better economic prospects. In the long term, there will be between 200,000 and 250,000 more people in the job market.[66] The promotion of education and training, immigration and the work-life balance is intended to counteract the existing shortage of skilled labour in some sectors of the economy.

The Federal Government is supporting structural change in coal regions with wide-ranging investments. The goal is to support affected regions during the transition. The coal phase-out requires political and structural measures to drive job creation in forward-looking industries, and so support positive change. The Federal Government plans to provide up to 40 billion euros by 2038 for structural change to turn the coal regions into future regions. Many forward-looking projects are being initiated in the affected regions in Brandenburg, North Rhine-Westphalia, Saxony and Saxony-Anhalt to consolidate the positive change in the coal regions and create new jobs. To increase innovation and competitiveness in these regions, the aim is to attract businesses and highly skilled workers, and expand supporting infrastructures. Research institutions are being funded, and universities and businesses are receiving support to position themselves in innovative sectors. They are encouraged to join forces in innovation ecosystems to create new jobs and generate innovations. Innovation is being promoted in special regional partnership projects. Project ideas to promote sustainable tourism can also be supported. New tourist attractions are creating a new sector of the economy, which in turn is creating new jobs in the region in question. With the projects approved by the end of August 2020, the goal of creating 5,000 new jobs in the coal regions by 2028 is likely to be achieved.[67] In addition, sustainable regional restructuring is being targeted across all regions, for example by creating near-natural areas and bodies of water.

The transformation of transportation is creating new digital business models in the mobility sector. One example of this is the market growth in the sharing economy, platform solutions and "Software as a Service".[68] For example, the car-sharing market has grown by more than ten per cent annually in recent years.[69] Since batteries account for 40 per cent of the added value of electric cars, the growing battery market is also linked to the mobility transition. International demand for battery capacity is likely to increase tenfold by 2030.[70]

> ***"It is important to use the economic opportunities for regions affected by structural change. At the same time, we must initiate a social debate on the cultural identity of areas in transition."*** *BMWK, Annual Economic Report 2022, foreword by Federal Minister Dr. Robert Habeck*

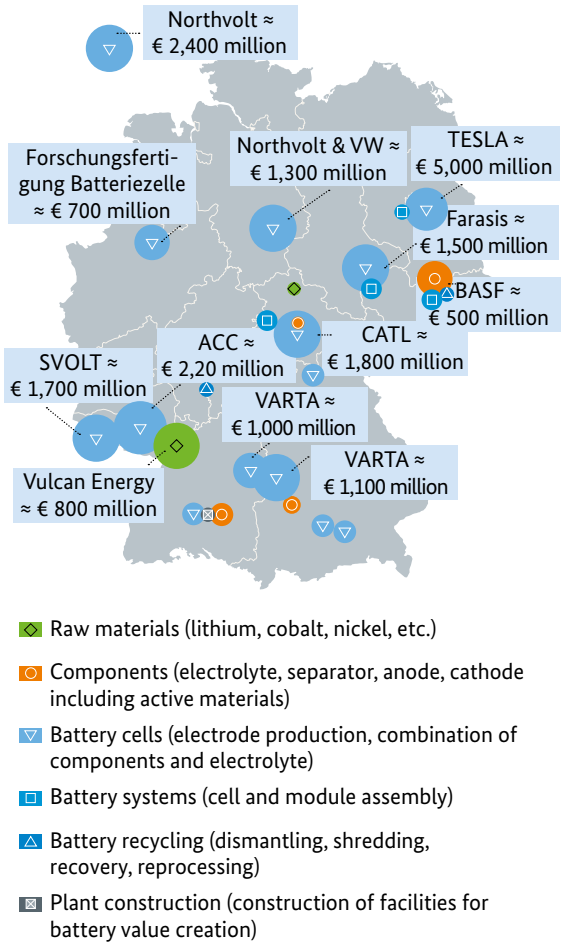
The battery sector will create around 100,000 new jobs across Europe by 2030. Within Europe, 20 "gigafactories" – large-scale production sites – are planned. By then, 46 billion euros will have been invested in battery projects, 21 billion euros of which will be in Germany. The fact that seven of the gigafactories are to be built in Germany highlights the country's ascendant market position.[71] Substantial investments are also planned in other segments of the value chain in Germany by 2030 (see Figure 45). Compared to the Asian battery sector, European battery manufacturing sites can operate with lower emissions due to the high share of renewables in the electricity supply.

Europe is expected to supply one third of the global battery market by 2030. At the European level, too, the aim is to secure jobs in the battery sector through extensive support programmes. The European Commission has launched two projects as part of the state aid instrument IPCEI, with the participation of 12 Member States. Around 60 companies are involved in the project, 15 of them from Germany.

Under the "Battery Cell Production Germany" initiative, the BMWK has introduced a raft of measures to promote the German battery sector. Along with funding of almost three billion euros, this will support knowledge transfer from research as well as cooperation between project partners from different areas of the value chain.

Budgets for research and development in the field of environmental protection and climate action have increased significantly in Germany and worldwide. This process is being driven in particular by renewable energy and, over the past decade, by innovative energy efficiency solutions and storage technologies. Measured by patent activity, Germany is currently one of the world's leading countries for environmental technologies.[72]

Figure 45: **Battery investment in Germany by 2030**



Source: BMWK (2021a)

4.3 Creating sustainable infrastructures

A sustainable infrastructure is the backbone of a greenhouse gas neutral economy and society. Infrastructure, like transport or power networks, refers to publicly used facilities. It includes energy grids, water supply, wastewater disposal and roads, as well as information and communication infrastructure.

The shift towards climate-friendly technologies and lifestyles is changing the demands on our infrastructure. For example, an increase in working from home and virtual meetings requires an expansion of the digital infrastructure in Germany. Electric vehicles need charging stations, not conventional filling stations. Transitioning the energy supply to renewable energy together with electrification of larger portions of energy consumption – for example through electromobility – requires an expansion of electricity transmission and distribution networks.

At the same time, infrastructures are adversely affected by climate change. Creating sustainable infrastructure therefore also refers to the inclusion of adaptation measures. For example, upgrading wastewater pipelines enhances the climate resilience of infrastructure. Given the increasing frequency of torrential rainfalls, the municipal drainage systems must be prepared to handle and dissipate higher volumes of water. Building resilient infrastructures is essential to enable sustainable development. This is not only an aim of the Federal Government and European Commission, it is also the ninth United Nations Sustainable Development Goal.

The tasks ahead require a faster pace of infrastructure development. The associated procedures, decision-making and implementations must be significantly speeded up. Therefore, the Federal Government plans to modernise, debureaucratise and digitalise planning and approval procedures, and increase personnel capacities. By involving citizens earlier, infrastructure planning should become faster and more efficient. For particularly high-priority projects, the Federal Government will in future impose short deadlines for issuing the prescribed planning approval decision, following the model of the Federal Immission Control Act (BImSchG).

There is a great need for action in power grid development planning. To bring about the transformation of the energy system, planning for the key infrastructures will be based on the overarching long-term goal, i.e. greenhouse gas neutrality in 2045. In addition, the energy supply infrastructure needs to be modified and expanded at a faster pace to facilitate an energy system based on renewables and a close dovetailing of the sectors. To achieve this, the Federal Government wants to move away from planning the electricity, natural gas, hydrogen and heat grids independently of each other. What is needed instead is a so-called system development strategy that sets out a common framework for the various infrastructures.

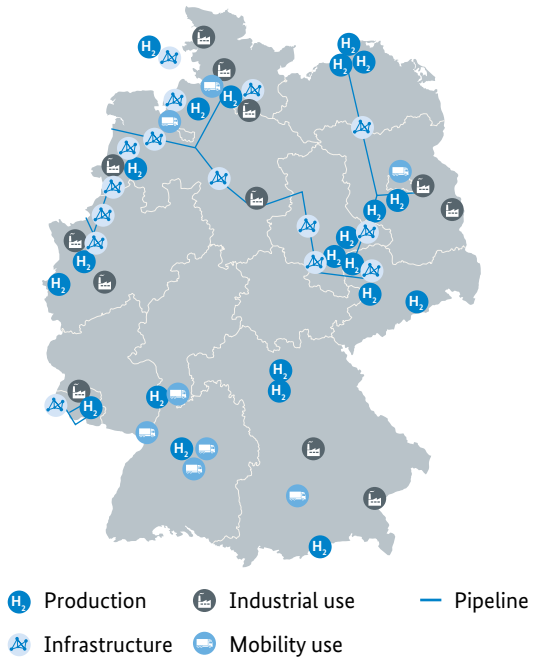
At the level of the transmission and distribution networks, the necessary expansion of the electricity grid is faltering. As of Q1 2022, of the 101 projects under the BBPlG and the Energy Line Expansion Act (EnLAG) with a length of about 12,300 kilometres, only 2,005 kilometres had been completed, and a further 1,126 kilometres had been approved and were pending under construction. A total of 9,500 kilometres are still awaiting or going through the approval process.

Infrastructure planning also involves the ambitious expansion of offshore wind farms and their connection to the grid. For the distribution networks, grid expansion planning must be further developed into an integrated grid plan. The goal is forward-looking and efficient demand sizing that also takes the development of other sectors and consumption control measures into account.

There will be infrastructure development in the heat supply sector, too. To enable nationwide municipal heat planning, the Federal Government is seeking to

> *"We want to generate 80 per cent of our electricity from renewable energies in less than nine years. To achieve this, we need not only more wind turbines and more solar plants, but also expanded electricity grids. Grid expansion is the prerequisite for supplying Germany reliably and cheaply with renewables. And driving it forward quickly is an extremely demanding task."*
> *Dr. Robert Habeck, Federal Minister for Economic Affairs and Climate Action, visit to the Federal Network Agency, February 2022*

Figure 46: **62 German hydrogen projects as part of the European IPCEI hydrogen project**



Source: BMWK (2021b)

create a legal orientation framework (Municipal Heat Planning Act) together with the Länder. On 1 January 2022, the Centre of Competence for the Municipal Heat Transition (KKW) – offering information and advisory services for municipal authorities – was launched in Halle an der Saale. Furthermore, the federal funding programme for efficient district heating networks (Bundesförderung für effiziente Wärmenetze; BEW) promotes the expansion and decarbonisation of heating networks.

The Federal Government is committed to the rapid implementation of the Important Project of Common European Interest for Hydrogen (IPCEI Hydrogen). IPCEI Hydrogen aims to promote integrated projects along the entire hydrogen value chain – ranging from the production of green hydrogen to infrastructure as well as the use of hydrogen in industry and for mobility. It will also financially support investments in the development of a hydrogen grid infrastructure (around 1,700 kilometres). These IPCEI projects (see Figure 46) should now be implemented quickly to help Germany become a lead market for hydrogen technologies by 2030.

The 2020s are to be used for a new departure in mobility policy, to enable sustainable, efficient, barrier-free, intelligent, innovative and affordable mobility for all. This requires the development and expansion of climate-friendly infrastructures, including the rail network, cycle paths and charging stations for electric vehicles. Various measures are planned in this regard.

For example, the Federal Government will continue to develop the Rail Transport Master Plan and double passenger traffic (see also Section 3.4). The targeted timetable for a coordinated clock-face scheduling system throughout Germany (known as "Deutschlandtakt") and associated infrastructure capacity will be aligned with these goals.

In addition, the Länder and municipalities will be provided with resources to improve the attractiveness and capacity of public transport. The aim is to significantly increase passenger numbers on public transport.

The National Cycling Plan is to be implemented and updated. The expansion and modernisation of the cycle path network and the promotion of municipal cycling infrastructure will also be pursued. To increase bicycle use, the Federal Government will guarantee funding until 2030 and promote the combination of cycling and public transport. It will provide structural support for walking, underpinned by a national strategy.

4.4 Municipal climate action

The far-reaching transformation towards greenhouse gas neutrality must also take place at the level of districts, cities and municipalities. Funding programmes such as those of the National Climate Initiative (NKI) serve to support municipal climate action. For example, municipalities receive support to help them prepare climate action concepts, invest in climate-friendly mobility as well as water and waste management, and implement innovative model projects.

The most important municipal funding programmes under the NKI are the Municipal Guideline as well as competitive funding calls for municipal climate action model investment projects, such as "Climate Action Through Cycling". The Municipal Guideline covers the main municipal areas of action with funding opportunities for strategic, conceptual and investment climate action projects. From its launch in 2008 until the end of 2021, the NKI had provided support worth around 965 million euros for some 21,500 projects in almost 4,500 municipalities, triggering investments totalling around 2.5 billion euros. This support for investment projects has led to a reduction of greenhouse gas emissions by a total of about 7.7 million tonnes CO_2 equivalent (net over the project duration). Further reductions of 12.6 million tonnes CO_2 equivalent (net over the project duration) have resulted from strategic climate action projects, including the funding of staff positions in climate action management.

A central support component is the funding of staff positions for climate action management in municipal administrations. Current research results demonstrate the positive effects of climate action management:[73] cities, municipalities and districts with climate action management implement three times as many supported climate action measures, which are also larger than in municipalities without climate action management. In addition, a greater number of different support components are utilised. Ultimately, up to nine times more greenhouse gas emissions can be saved in each municipality with climate action management than in municipalities without climate action management. Climate action management enables municipalities to implement more and larger measures. So equipping municipalities with climate action personnel makes a very significant contribution to greenhouse gas reduction.

21,500 projects

have been supported by the NKI within the framework of the municipal directive from 2008 to the end of 2021.

The latest NKI research project on the impact potential of municipal measures on national climate action not only shows the positive impact of climate action management, it also highlights the great importance of municipal action in general for the transformation towards greenhouse gas neutrality. Based on 38 quantified measures in the four municipal spheres of influence (consumption and example-setting, utilities and services, regulation and planning, advice and motivation), it was found that municipalities can influence greenhouse gas emissions to the tune of 101 million tonnes CO_2 equivalent (based on the year 2019).[74] That corresponds to about one eighth of Germany's total emissions. The analysis makes it clear that in order to achieve greenhouse gas neutrality, municipalities must implement highly ambitious measures in all areas of influence. Prioritising individual areas of action is not sufficient. Better framework conditions are still needed to widen the geographical scope and duration of municipal climate action, and thus exploit the full climate action potential in municipalities.

4.5 Sustainable investments

Climate action requires a consistent alignment of financial flows with climate targets. Currently, institutional and private investors continue to invest primarily in companies whose business models are not compatible with the international climate targets. Examples of this include coal, oil and gas companies. To mitigate global climate change, these investments must be directed towards climate-friendly sectors.

Investments in business concepts based on fossil resources are also increasingly becoming a risk for investors, as they threaten to become stranded assets. This means assets would have to be given up before the end of their planned economic lifetime, as they are no longer profitable in a future economy focused increasingly on climate neutrality. Investors are therefore working to identify long-term climate

risks systematically and in good time, and adapt their investment strategy accordingly. The main focus is on divestment (withdrawing capital) from companies whose business models are based on delivering and using fossil fuels, and investing in climate-friendly companies instead.

Bringing global financial flows into line with low-emission and climate-resilient development is a central task for the international community. Current trends are already moving in this direction. In Germany, for example, the proportion of sustainable investments in the overall investment volume has been increasing for years and amounted to 11.6 per cent in 2021 (see Figure 47). However, this trend needs to accelerate significantly. To this end, the Federal Government is pursuing a policy that substantially increases investments – both private and public. Given a high level of investment-seeking capital, this is a favourable opportunity for capital-intensive change.

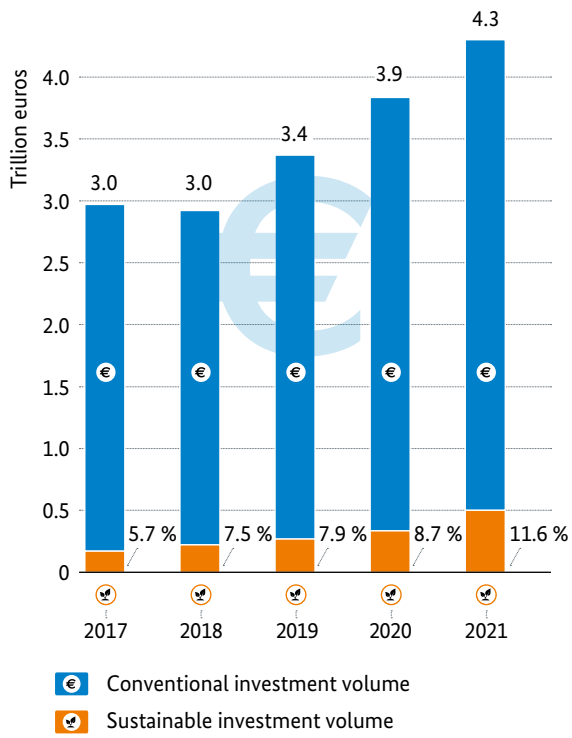
The Federal Government wants to ensure that more private capital is mobilised for transformation projects, because private-sector investment in climate-neutral buildings, power plants and industrial facilities, infrastructures and mobility systems is at the heart of the transformation towards a climate-neutral economy. To incentivise private investment, the Federal Government would also like to be able to securitise risk with the help of the capital markets via its public development banks. Both the future fund for startups and the financing model for public infrastructure investments offer possibilities for this. The German National Development Bank (Kreditanstalt für Wiederaufbau) can also play a stronger role as an innovation and investment agency.

The Energy and Climate Fund will be developed into a Climate and Transformation Fund (KTF). To provide additional resources for the fund, 60 billion euros were transferred to the Energy and Climate Fund in a second supplementary budget in 2021. This money is earmarked for additional climate action measures and measures to transform the German economy. This is intended to cushion the impacts of the COVID-19 pandemic by catching up on investments to confront climate change and transform the German economy. At the same time, the KTF will address current risks to the economy and public finances resulting from the global climate crisis.

Subsidies and spending that harm the environment and climate will be eliminated. Subsidies and expenditures that harm the environment and climate are an obstacle to the development and competitiveness of climate-friendly products and jeopardise the achievement of climate goals. According to the Federal Government's 28th Subsidy Report, tax concessions amounting to approximately seven billion euros have a damaging effect on the climate. According to UBA estimates, all explicit and implicit environmentally harmful subsidies in Germany totalled 65.4 billion euros in 2018 (see Figure 48).

The Federal Government wants to create an investment premium for climate action and digital assets.

Figure 47: **Share of sustainable financial products in total German investment volume**



Sustainable investments: Financial instruments in which a minimum share is invested in (ecologically) sustainable assets and sustainability factors are taken into account. All products classified as Article 8 products or Article 9 products according to the EU Sustainable Finance Disclosure Regulation are considered sustainable.

Source: FNG (2022)

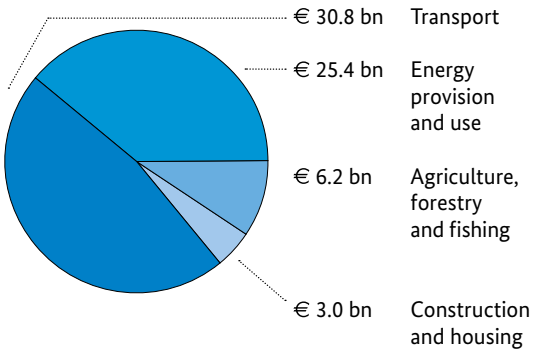
This would enable taxpayers, for a limited period of time, to deduct from their taxable profit a proportion of the cost of fixed assets that serve these purposes ("super depreciation").

Germany is to become the leading location for sustainable finance. To this end, the Federal Government wants to create a suitable framework for sustainable financial products, following a guiding principle of financial stability. Furthermore, in 2020 the Federal Government launched the first issue of Green Bonds (Grüne Bundeswertpapiere) based on established international market standards, together with the "Green Bond Framework" of 24 August 2020.[75] Both the number and volume of issues of Green Bonds, as well as the terms, have steadily increased since 2020. Further green Federal bonds are to be issued in the coming years. The resulting green yield curve serves as a benchmark and establishes the Federal Government's benchmark-setting role as an issuer in the green segment. The issuing of Green Bonds is accompanied by comprehensive reporting. In this way, the Federal Government creates transparency about its spending on climate action and environmental protection.

The Federal Government is also committed to establishing a uniform, credible transparency standard for sustainability information for businesses at the European level. Moreover, it supports European minimum requirements in the market for environmental, social and governance ratings ("ESG ratings"), and the mandatory consideration of sustainability risks in credit ratings issued by the major ratings agencies. In addition, environmental and, where applicable, social values are to be integrated into existing accounting standards in dialogue with the business community, starting with greenhouse gas emissions.

The Federal Government also supports the European Commission's plan to develop a Corporate Sustainability Reporting Directive, which has already entered trilogue negotiations. The Directive will impose an obligation on large companies to disclose information on what they are doing to address social and environmental challenges. The Federal Government also plans to implement a credible sustainable finance strategy with international reach, based on the recommendations of the Sustainable Finance Council. The sustainable finance strategy pursues five goals:

Figure 48: **Environmentally harmful subsidies in 2018**



Source: UBA (2021a)

- advance sustainable finance globally and at the European level;
- seize opportunities, finance transformation, mainstream sustainability impact
- target improvements in risk management in the financial industry and ensure financial market stability;
- strengthen Germany as a financial centre and expand its expertise;
- establish the Federal Government as a role model for sustainable finance in the financial system.[76]

The Sustainable Finance Council will continue as an independent and effective body.

5. Glossary

Circular economy

Production and consumption model in which existing materials and products are shared, re-used, repaired, reprocessed and recycled for as long as possible. This is to extend product life cycles and to minimise waste. The circular economy contrasts with the traditional, linear economic model ("throw-away economy").

Climate impact

Degree of climate-related harmfulness of one molecule of greenhouse gas. The climate impact of carbon dioxide is used as a benchmark, based on which the climate impact of other greenhouse gases is defined. The climate impact of a molecule is expressed in terms of an equivalent quantity of CO_2 (CO_2 equivalent).

Climate neutrality

According to the IPCC, climate neutrality describes a state in which human activities have no net impact on the climate system. Accordingly, all activities that influence the climate system through greenhouse gas emissions and through biogeophysical effects must cease or be offset. These include emissions of cooling aerosol particles, causing warming vapour trails, as well as land use changes that affect how the earth's surface reflects and absorbs solar radiation ("albedo effect").

CO_2 equivalent

Unit for the greenhouse warming potential of gas; makes it possible to compare emissions from different gases. CO_2 equivalent shows what warming effect a quantity of gas would have represented as an equivalent quantity of CO_2 over a 100-year period.

Council of Experts on Climate Change

The Council of Experts on Climate Change comprises five leading scientists appointed by the Federal Government to help apply the Federal Climate Change Act. The Act also defines the responsibilities of the expert council: the council releases statements when the Federal Government plans to change the permitted annual emission volumes in the Federal Climate Change Act, updates the Climate Action Plan and adopts additional climate action programmes. In addition, the Bundestag or the Federal Government can also commission the council to draft special reports.

Decarbonisation

Transformation of social and economic systems with the aim of moving away from the use of carbon-based energy sources.

EEG levy

The EEG levy was introduced in 2000. Also called the "green electricity levy", it served to finance support for the expansion of solar and wind energy as well as biomass and hydropower plants. It was levied on end customers via their electricity bills. Revenues from the EEG levy flowed into the so-called EEG account of the transmission system operators (TSOs). The EEG levy was permanently abolished on 1 July 2022. In future, the financing requirements for renewable energies will be met via the Federal budget. This means that TSOs will be entitled to claim reimbursement of their costs from the Federal Republic of Germany.

Effort sharing

Effort sharing aims to achieve a just distribution of effort in reducing greenhouse gases in European climate policy and therefore allocates a total emission volume to each individual Member State, which is calculated based on the per capita income in the Member States. The Effort Sharing Regulation (ESR) therefore defines binding emission reduction targets for every EU Member State for the period leading up to 2030.

Electricity generation costs
The most common comparison value in electricity generation is the cost of producing the electricity. Electricity generation costs are a measure that relates the cost of building a plant and its annual operating costs to the amount of electricity it generates over its lifetime.

EU Emissions Trading System (EU ETS)
The EU ETS is a trading system with a fixed upper limit for the total volume of specific greenhouse gas emissions that plants under its purview can release. The upper limit decreases over time, reducing overall emissions. Within this upper limit, companies receive or purchase emission allowances (at auction), which they can trade as required. Each company is obliged to submit sufficient allowances for its total emissions at the end of the year. If they fail to do so, they are liable to pay significant fines.

Final energy
Final energy is defined as the part of primary energy that reaches consumers after deduction of transfer and conversion losses, for example in the form of district heating, electricity, petrol, heating oil, natural gas, biogas and hydrogen.

Greenhouse effect
Greenhouse gases raise the average temperature on the surface of the earth via what is known as the greenhouse effect. Short-wave solar radiation warms the earth's surface, which then emits long-wave infrared radiation. This is re-emitted back to the earth's surface by the greenhouse gases. As a result, less energy is returned to space and the temperature on the earth's surface increases. A distinction is made between the natural greenhouse effect, which has always taken place since the formation of the earth's atmosphere – it is what makes life on earth possible in the first place (without natural greenhouse gases, the average global temperature would be around -15°C) – and the additional anthropogenic greenhouse effect.

Greenhouse gas neutrality
Reached when the total of emissions (for example from burning fuels) and absorption (for example by natural sinks, future technologies) of human-made greenhouse gas emissions is zero.

Gross final energy consumption
In addition to the final energy consumption, the gross final energy consumption incorporates self-consumption of generation plants and transmission losses. It is the reference figure for calculating the share of renewable energy sources per EC Directive 2009 / 28 / EC to promote the use of energy from renewable sources.

Hydrogen
Hydrogen can exist as a gas and is a very common element on earth, but it is found almost exclusively in chemical compounds (water, acids, hydrocarbons, etc.) Hydrogen is, for example, produced by splitting water (H2O) into oxygen (O) and hydrogen (H2). Hydrogen is a sustainable, versatile, easy-to-transport and therefore promising fuel for the energy transition if produced using renewable energy sources.

Primary energy consumption
Mathematically used energy content of a naturally occurring energy source such as sun or crude oil before it is converted into another form of energy, a "secondary energy carrier". Accordingly, primary energy consumption refers to the energy available directly in the energy sources.

Sink
Reservoir that can absorb and store carbon temporarily or permanently. Forests and oceans are major sinks.

6. Abbreviations

°C	Degrees Celsius
ANK	Federal Action Plan on Nature-based Solutions for Climate and Biodiversity (Aktionsprogramm Natürlicher Klimaschutz)
BauGB	Town and Country Planning Code (Baugesetzbuch)
BBPlG	Federal Requirements Plan Act (Bundesbedarfsplansgesetz)
BECCS	Bioenergy with carbon capture and storage
BMDV	Federal Ministry for Digital and Transport (Bundesministerium für Digitales und Verkehr)
BMEL	Federal Ministry of Food and Agriculture (Bundesministerium für Ernährung und Landwirtschaft)
BMUV	Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz)
BMWK	Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz)
BMWSB	Federal Ministry of Housing, Urban Development and Building (Bundesministerium für Wohnen, Stadtentwicklung und Bauwesen)
bn	Billion
BnatSchG	Federal Nature Conservation Act (Bundesnaturschutzgesetz)
CAP	Common Agricultural Policy
CBAM	Carbon Border Adjustment Mechanism
CCfD	Carbon Contracts for Difference
CCS	Carbon capture and storage
CCU	Carbon capture and use
CH_4	Methane
cm	Centimetre
CO_2	Carbon dioxide
COP	Conference of the Parties
DACCS	Direct air carbon capture and storage
DACCUS	Direct air carbon capture, utilisation and storage
DLR	German Aerospace Centre (Deutsches Zentrum für Luft- und Raumfahrt)
DWD	German Weather Service (Deutscher Wetterdienst)
EEG	Renewable Energy Sources Act (Erneuerbare-Energien-Gesetz)
ERK	Council of Experts on Climate Change (Expertenrat für Klimafragen)
EKBG	Substitute Power Plant Maintenance Act (Ersatzkraftwerkebereithaltungsgesetz)
EnSiG	Energy Security Act (Energiesicherungsgesetz)
EnWG	Energy Industry Act (Energiewirtschaftsgesetz)
ESR	EU Effort Sharing Regulation
etc.	Et cetera
EU	European Union
EU ETS	EU Emissions Trading System
GEG	Buildings Energy Act (Gebäudeenergiegesetz)
Gt	Gigatonne(s)
GW	Gigawatt
h	Hour(s)
HGV	Heavy goods vehicle
IAB	Institute for Employment Research (Institut für Arbeitsmarkt- und Berufsforschung)
IEA	International Energy Agency
IKI	International Climate Initiative (Internationale Klimaschutzinitiative)
IPCC	Intergovernmental Panel on Climate Change
IPCEI	Important Project of Common European Interest

JETPs	Just Energy Transition Partnerships
km	Kilometre
KTF	Climate and Transformation Fund (Klima- und Transformationsfonds)
kWh	Kilowatt hour(s)
LTS	Long-term strategy
LULUCF	Land use, land use change and forestry
mm	Millimetre
N_2O	Nitrous oxide
NABEG	Transmission Grid Expansion Acceleration Act (Netzausbaubeschleunigungsgesetz Übertragungsnetz)
NDCs	Nationally Determined Contributions
NKI	National Climate Initiative (Nationale Klimaschutzinitiative)
ppm	Parts per million
PV	Photovoltaics
TSO	Transmission system operator
TWh	Terawatt hours
UBA	German Environment Agency (Umweltbundesamt)
UNFCCC	United Nations Framework Convention on Climate Change
WindBG	Wind Land Requirements Act (Windflächenbedarfsgesetz)
WindSeeG	Offshore Wind Energy Act (Windenergie-auf-See-Gesetz)
WMO	World Meteorological Organization

7. Endnotes

1. IPCC (2021b)
2. IPCC (2021c)
3. Climate College (2016), Met Office (2022), NOAA (2022)
4. WMO (2022), the IPCC report assumes a global temperature increase of 1.09°C compared to the 1850 to 1900 period, based on the average of 2011 to 2020 (www.ipcc.ch, p. 9)
5. GEOMAR (2018)
6. IPCC (2021c)
7. IPCC (2021c), NASA (2022)
8. Kixmüller (2022)
9. IPCC (2021c)
10. IPCC (2021c)
11. IPCC (2022a)
12. IPCC (2022a)
13. IPCC (2022b)
14. IPCC (2022b), IPCC (2022c)
15. IPCC (2022a)
16. DWD (2021)
17. Deutsches Klima-Konsortium et al. (2021)
18. DWD (2022c)
19. DWD (2022c)
20. IPCC (2022a)
21. UBA (2021b)
22. BMEL (2022a)
23. DFWR (2021)
24. BMEL (2021a)
25. BMWK (2022c)
26. BMWK (2022c)
27. EEA (2021c)
28. EEA (2022)
29. European Commission (2021a)
30. European Commission (2021b), European Commission (2022)
31. European Commission (2021c)
32. Federal Foreign Office (2021)
33. EDGAR (2021)
34. BMWK (2022c)
35. UBA (2022a)
36. UBA (2022a)
37. Agora Energiewende (2022b)
38. AG Energiebilanzen (2022)
39. UBA (2022g)
40. Federal Network Agency (2022a)
41. Destatis (2022c)
42. BMWK (2020b)
43. Federal Network Agency (2022b)
44. dena (2019)
45. DIW (2020)
46. BMUV (2021c)
47. Ecornet (2022)

48. Federal Government (2022b)
49. BMUV (2021c)
50. UBA (2022c)
51. BMEL (2022b)
52. BMEL (2022c)
53. UBA (2021c)
54. BMUV (2021c)
55. Destatis (2021)
56. BMEL (2021b)
57. DLR (2022)
58. Bundesrat (2021)
59. Five current key climate neutrality studies for Germany are "Long-term studies for the transformation of the energy system in Germany 3" by BMWK, "Climate-neutral Germany 2045" by the Climate Neutrality Foundation, Agora Energiewende and Agora Verkehrswende, "Climate paths 2.0 – An economic programme for climate and the future" by BDI, the dena pilot study "Towards Climate Neutrality", and the model and scenario comparison "Germany on the way to climate neutrality 2045" by the Ariadne consortium funded by the Federal Ministry of Education and Research. The Ariadne project provides an overview of the five studies at: www.ariadneprojekt.de
60. Agora Energiewende (2021)
61. Prognos, Öko-Institut, Wuppertal Institute (2021)
62. Ariadne-Projekt (2021b)
63. BMUV (2021b)
64. FfE (2022)
65. Federal Network Agency (2021)
66. IAB (2022)
67. German Bundestag (2021)
68. Software as a Service describes a model whereby software is offered to customers as a service which they access through suitable IT hardware. The software itself and the associated IT infrastructure are operated by external service providers.
69. BMUV (2021b)
70. BMWK (2022d)
71. BMWK (2021a)
72. UBA (2021d)
73. Results of the BMWK-UBA project "Impact potential of municipal measures for national climate action. Impacts of nationwide strategic climate action elements and their potential for the NKI."
74. Advance publication "Climate action potentials in municipalities. Quantitative and qualitative assessment of greenhouse gas reduction potentials in municipalities": www.umweltbundesamt.de
75. German Finance Agency (2022)
76. BMF (2021)

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