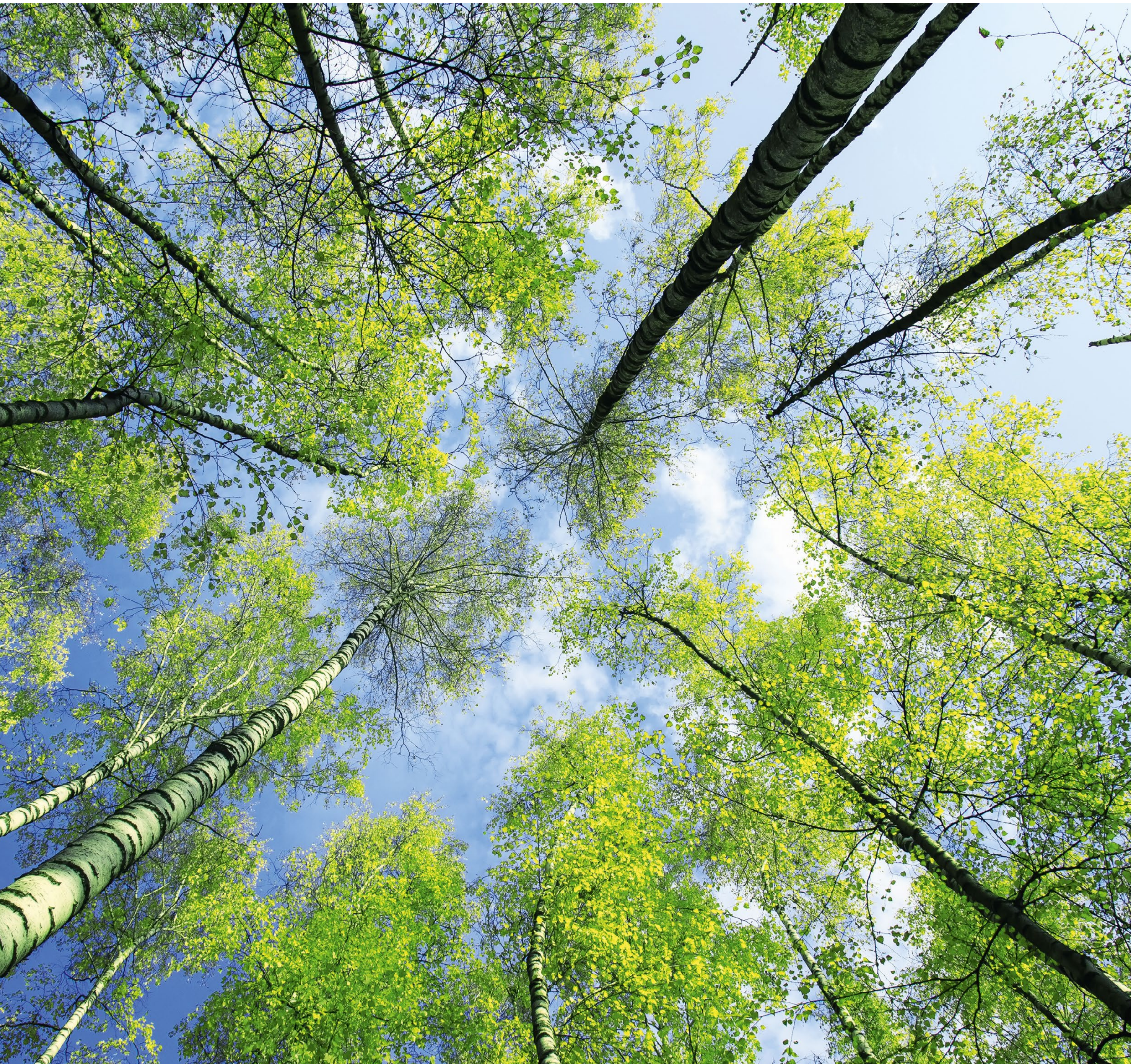
WORLD ENERGY COUNCIL | WELTENERGIERAT DEUTSCHLAND

# Pathways to Climate Neutrality

## English version of the featured topic in 2020's "Energie für Deutschland"



## Publishing details

Energie für Deutschland 2020
Editorial deadline: April 2020

## Publisher:

Weltenergierat – Deutschland e.V.
Gertraudenstraße 20 | 10178 Berlin
Germany
T (+49) 30 2061 6750
E info@weltenergierat.de
www.weltenergierat.de
WEC_Deutschland

**Responsible according to German press law:**
Dr Carsten Rolle, Secretary General

**Editors:**
Energie für Deutschland editorial group, Chair: Dr Hans-Wilhelm Schiffer
Robin Höher, Flavia Jakob, Nicole Kaim-Albers, Christoph Wüstemeyer

## Printing:

DCM Druck Center Meckenheim GmbH
www.druckcenter.de

**Photo credits:**
Cover: © nataba – stock.adobe.com

# Pathways to Climate Neutrality

The World Energy Council – Germany expresses its gratitude to the authors
Prof. Dr Stefan Ulreich (Hochschule Biberach), Dr Karl Schönsteiner and
Dr Volkmar Pflug (Siemens Gas and Power GmbH & Co. KG) for this article.

# Executive Summary

In policy debate, the term “climate neutrality” is used at various levels. Increasing numbers of companies, countries, and even the European Union are professing this goal. The meaning of the term is often unclear, and the measures to achieve the goal are manifold. Climate neutrality is already enshrined in the Paris Agreement as a balance between anthropogenic emissions by sources on the one hand and removals by sinks of greenhouse gases on the other. The target date has been set as the middle of this century. The policy and technological measures for climate protection vary in terms of maturity and cost, and each country and company faces their own unique conditions, as well as differing levels of ambition with respect to climate protection measures. Despite all these differences, it is possible to draw conclusions from comparison, and analyse what actions are still needed in order to achieve the Paris goal of climate neutrality.

1. **Emissions are expected to increase up to 2030.** This is mainly due to the economic development of various emerging markets, which is expected to continue over the coming years. One indicator of this is the $CO_2$ emissions per capita. A comparison of India with Japan clearly illustrates this; Japan, an industrialised country, emits 10.17 t $CO_2$ per capita, while India, a country where over 230 million people have no access to electricity, emits just 2.23 t $CO_2$ per capita.

2. The strategies and objectives for climate protection are different in every country. **Often, climate protection is not the priority, but rather part of a whole range of policy objectives** that a government would like to achieve. These may even conflict with each other. For example, access to energy is a high priority in many countries in order to achieve other development goals, such as education, nutrition, health, and economic growth.

3. **Climate protection is being implemented in part at the local and regional levels.** Although the United States is withdrawing from the Paris Agreement, U.S. states with ambitious climate targets and standards are joining an international Climate Ambition Alliance. In addition, important climate protection standards in one state are copied in other states, and thus have a cross-border impact. In China, experience with emissions trading systems gained at the regional level is now being shared at the national level. In individual cases, greater climate protection is being implemented at the level of China’s major cities in order to provide scope for action in other parts of the country.

4. **In addition to policy, market developments have an important influence on climate protection.** Due to the competitive advantages of natural gas over coal, the United States has been able to reduce its $CO_2$ emissions in the electricity sector by 25 percent in recent years; there, the share of natural gas in electricity generation has doubled since 2000, while the share of coal has fallen from 50 percent to 30 percent. Policymakers need to anticipate market developments and combine an openness to various technologies with climate protection.

5. **Even the ambitious national climate plans currently only include measures to reduce greenhouse gas emissions,** such as the expansion of renewable energies, electrification, energy efficiency, changes in consumption behaviour, or the use of low-emission fuels/hydrogen. In a few countries, the use of carbon capture and utilisation/storage plays a role, albeit on a smaller scale, and the recycling of $CO_2$ is being further developed in some projects. However, few countries have integrated the import of climate protection services from abroad or negative emissions technologies (NET) into their strategies.

6. **Companies are increasingly professing climate neutrality.** The costs for climate protection measures increase proportionately with the level of ambition. Measures are introduced for competitive advantages, but also to comply in full or in part with legal frameworks and investor demands.

7. **Carbon credits will play a major role in companies achieving climate neutrality,** so measures will often have no direct systemic influence on the achievement of a country’s climate protection targets. In a cap-and-trade system, for example, the total emissions are capped, regardless of emissions or savings. The feed-in priority of renewable energies means that it is not market demand but technical limitations or existing capacities that limit the amount of renewable electricity in the system.

8. In addition to greenhouse gas emissions at the country level, emissions remain at the company level that can only be reduced with great difficulty or at high cost. This, consequently, creates the need for “negative emissions” to remove greenhouse gases from the atmosphere. **The later the target of a complete reduction of all anthropological greenhouse gas emissions is achieved, the greater the need for negative emissions technologies and greenhouse gas sinks will be.** According to the Intergovernmental Panel on

Climate Change (IPCC), in order to achieve the 1.5 °C target, all GHG emissions have to be net zero by 2067 at the latest.

9. **Negative emissions technologies are still in the early stages of development and application.** The following negative emissions technologies or greenhouse gas sinks appear to be the most promising today: afforestation, biomass-energy with carbon capture and storage (BECCS), biochar for use in the soil, direct air carbon dioxide capture and storage (DACCS), and soil carbon sequestration, including through biomass growth. Other technologies under discussion include enhanced weathering, increasing the alkalinity of oceans, and ocean fertilisation. Negative emissions technologies and $CO_2$ sinks diverge in terms of their states of development, the cost per ton of $CO_2$ absorbed, their physical limitations, and their impact on the environment. Afforestation is currently the cheapest option, with a cost ranging from USD 5/t $CO_2$ to USD 50/t $CO_2$, while DACCS remains very expensive at this point in time, with a cost ranging from USD 100/t $CO_2$ to USD 300/t $CO_2$.

The analysis clearly shows that without the integration of negative emissions into climate protection strategies, the Paris climate targets are not achievable. This makes it all the more urgent for governments and society to discuss and promote the further development of these technologies. International exchange, also with regard to the trading of climate protection services, will be essential here, because each country has different geographical and structural conditions that determine the extent to which it can implement the climate protection measures that are necessary to achieve the net zero target. Transparency is central in the complex process of emissions accounting, so climate protection measures can be assessed and potentially prioritised, and double counting avoided. Early recognition of the relevance and promotion of negative emissions technologies by decision-makers from politics and business can lead to competitive advantages if climate protection ambitions are further bolstered at the international level.

# Introduction

Achieving climate neutrality is the goal of global climate policy; all anthropogenic greenhouse gas emissions (hereinafter referred to as GHG emissions) are no longer to have any influence on the climate. Many countries have already developed or are developing legislation or a strategy to achieve this goal by 2050 or earlier. In anticipation of stricter GHG emission limits, companies have committed themselves to reducing their GHG emissions to zero, in some cases well before 2050. The energy use and product selection of private households will be covered by regulation, and they can respond by changing their patterns of behaviour.

However, throughout the world, climate neutrality is interpreted differently in science, business, and politics (e.g., with or without compensation through greenhouse gas sinks[1] or with a focus on certain technologies). The target years from which a country or company wishes to be climate-neutral also differ. All in all, this results in a variety of pathways: countries orient themselves on national climate and emission targets, which are aggregated and based on global agreements such as COP21. Companies, however, orient themselves on economic value creation, which today is more international, and thus more cross-border than ever.

The strategies of countries and companies initially aim at reducing GHG emissions, typically by using resources more efficiently and applying emissions-free technologies. In addition, many parties also want to make greater future use of greenhouse gas sinks. Firstly, sinks serve to compensate for unavoidable GHG emissions; secondly, they can be a cheaper and faster alternative to reducing greenhouse gas emissions; and thirdly, these options can also be used to compensate for the historical emissions of a country or company.

These sinks can be realised in very different ways, either by making better usage of natural sinks (e.g., in forests or oceans), or by technological means to remove GHG emissions permanently and safely from the atmosphere. These negative emissions technologies thus present a viable option of going significantly beyond previous approaches to avoiding greenhouse gas effects and achieving the goal of climate neutrality in a reliable and planned manner.

However, the path to the long-term objectives is influenced by current events. Recurrent global crises have a lasting impact on the focus on the target, especially ex post. As a direct consequence of the coronavirus crisis in 2020, the issue of security of supply in the energy sector has been very much upgraded.[2]

The concept of a global economy based on the division of labour and global supply chains is being strongly called into question. Whether the many packages that have been put together to support the economy will be effective is something that no one can answer at this point in time. It is also uncertain to what extent the economic situation and prospects will determine the future actions of the involved parties. Moreover, in crisis situations, international coalitions can change once it becomes clear who will cooperate and who will not.[3]

It is still too early to form a clear picture of the overall situation. However, it should be evident to those countries that care about climate protection that their reaction to the coronavirus crisis and the manner in which they support severely affected countries can have a lasting impact on future climate coalitions. If economic activities can be stimulated with a focus on climate-friendly technologies, the crisis can be put to good use. In particular, process changes relating to energy efficiency and major changes to power plants are easier to implement in times of low plant utilisation than when plants are fully utilised, provided that the companies have sufficient capital. The increased use of telecommunications as a consequence of social distancing is an example that can have long-lasting positive effects.

This article shows the different ways in which countries and companies can achieve climate neutrality. There is a wide range of technological solutions available. Nevertheless, it is essential that a set of solutions is decided upon and implemented.

1 Carbon sinks serve as long-term stores of carbon dioxide, and can thus compensate for the effects of carbon dioxide and other greenhouse gases.

2 IEA, https://www.iea.org/topics/covid-19; EURELECTRIC, https://www.eurelectric.org/covid-19/; Energy Community, COVID-19: Security of energy supply monitoring (1 April 2020).

3 Matthias Müller, “China präsentiert sich bei der Coronavirus-Bekämpfung als Helfer und Freund von Ländern in Not”, Neue Zürcher Zeitung (25 March 2020); Andreas Wysling, “Russland, China und Kuba helfen Italien im grossen Stil – die Europäer sind zurückhaltender”, Neue Zürcher Zeitung (24 March 2020).

## 1.1 Climate neutrality

Climate neutrality was enshrined as an objective in Article 4 of the Paris Agreement: "… to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century …" According to current estimates, natural carbon dioxide sinks (e.g., soils, oceans, and forests) absorb between 9.5 and 11 Gt $CO_2$eq per year,[4] in contrast to global GHG emissions of 47.7 Gt $CO_2$eq in 2017.[5] As such, there are basically two levers for achieving climate neutrality: reducing GHG emissions and increasing their absorption by the various sinks.

> Global emissions total 47.7 Gt $CO_2$eq, whereas natural sinks absorb 11 Gt $CO_2$eq

In addition to carbon dioxide, global GHG emissions are comprised of other kinds of GHG, such as methane and nitrous oxide. The latter are converted into $CO_2$ equivalents, with different potential conversions depending on the assumed time horizon of the GHG in the atmosphere. The values from the IPCC Fourth Assessment Report are often used in this respect, where, given a time horizon of 100 years, one ton of methane ($CH_4$) is equivalent to 25 tons of carbon dioxide, and one ton of nitrous oxide ($N_2O$) is equivalent to 298 tons of carbon dioxide.[6]

Climate neutrality goes beyond carbon dioxide neutrality, as it considers all GHGs in terms of their impact on the climate, not just the impact of carbon dioxide (even if the latter accounts for the lion's share of GHG emissions). Carbon dioxide is also notable in terms of the various possibilities available to store the carbon dioxide present in the atmosphere in sinks, and thus mitigate its effect on the climate. In addition to natural sinks created by forests and oceans, technologies for negative emissions can also play a role here, such as bio-energy with carbon capture and storage (BECCS) technologies. Similarly, the anaero-

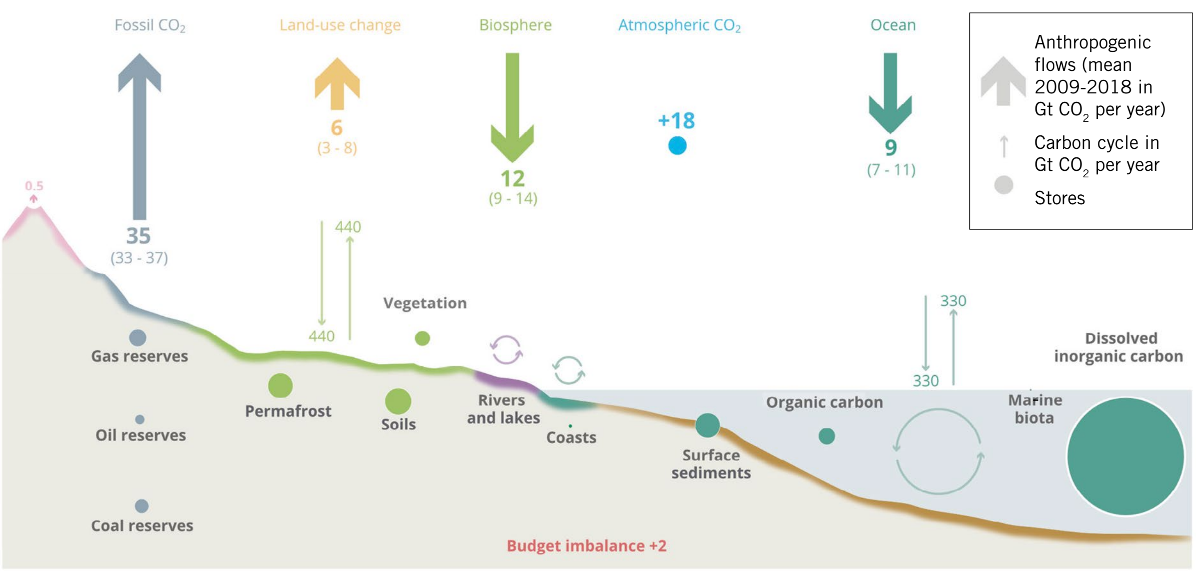
4 Le Quéré et al, Global Carbon Budget 2015, Earth System Science Data, Vol. 7, pp. 349-396, (2015).

5 Gütschow, J., Jeffery, L., Gieseke, R., Günther, A., The PRIMAP-hist national historical emissions time series (1850-2017), v2.1. GFZ Data Services (2019).

6 Forster et al., Changes in Atmospheric Constituents and in Radiative Forcing, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, United States, (2007).

7 Global Carbon Project, Carbon budget and trends 2019, [www.globalcarbonproject.org/carbonbudget] (4 December 2019).

**Figure 1.1: Sources and sinks in the carbon cycle**




The values presented are the means for 2009-2018 in Gt $CO_2$ per year. The budget imbalance is the result of inaccuracies in measurements. Sinks are also depicted.

Source: Global Carbon Project (2019)[7]

bic storage of wood (to prevent the release of $CO_2$ during the rotting process) combined with simultaneous afforestation has also been proposed.[8] Achieving negative emissions means the additional extraction of $CO_2$ from the atmosphere.

## Global energy consumption (transport, heating/cooling, electricity) accounts for around three-quarters of GHG emissions

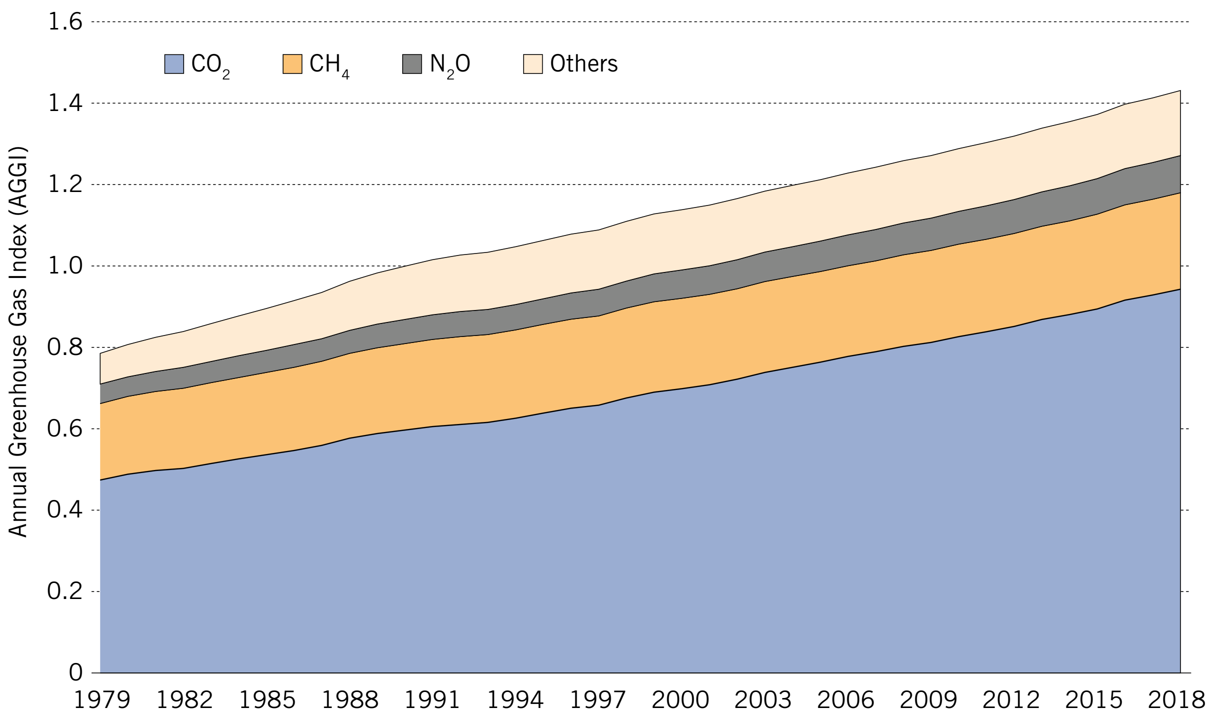
In order to describe the effects of GHGs on the Earth's radiation balance, the IPCC introduced the term "radiative forcing". The change in the global equilibrium temperature of the Earth bears a linear relationship with radiative forcing. The Annual Greenhouse Gas Index (AGGI) is defined as the ratio of total direct radiative forcing due to long-lived GHGs compared to the reference year 1990, the base year of the Kyoto Protocol. The index is published by the NOAA Earth System Research Laboratory to illustrate the effect of GHGs.[9]

Globally, carbon dioxide ($CO_2$) accounts for around three-quarters of total GHG emissions, followed by methane ($CH_4$) with 16.9 percent, and nitrous oxide ($N_2O$) with 4.5 percent. Other GHGs, the result of industrial activities, include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride ($SF_6$). Together, they account for around 2 percent of global GHG emissions. A climate-neutral approach could seek to compensate for the non-$CO_2$ emissions via $CO_2$ sinks, should a complete reduction of the non-$CO_2$ emissions prove impossible.

8 Ning Zeng, Carbon sequestration via wood burial, Carbon Balance and Management Vol. 3 Art. 1 (2008).

9 James H. Butler and Stephen A. Montzka, THE NOAA ANNUAL GREENHOUSE GAS INDEX (AGGI), NOAA Earth System Research Laboratory (updated spring 2019).

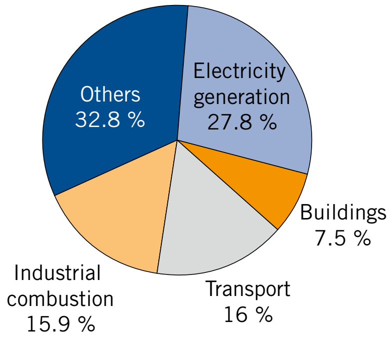
**Figure 1.2: Share of different greenhouse gases worldwide**



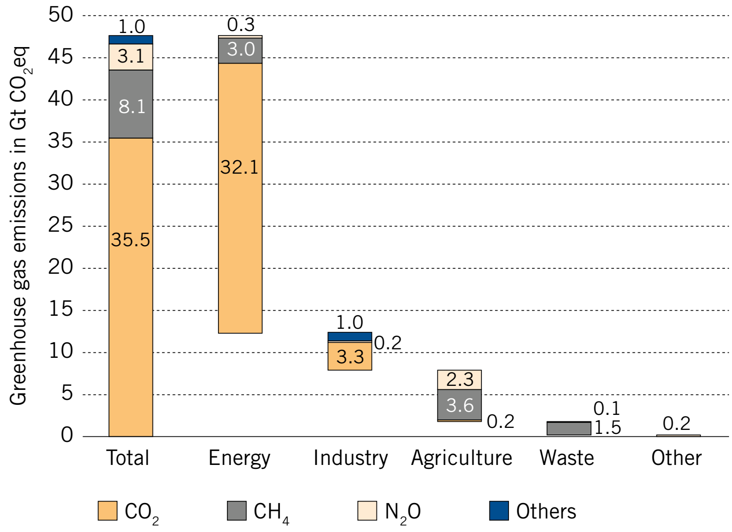

Carbon dioxide is responsible for almost two-thirds of the increase, followed by methane (around a sixth) and nitrous oxide (around one-sixteenth).

Source: NOAA

**Figure 1.3: Overview of the global sources of greenhouse gas emissions (2017)**

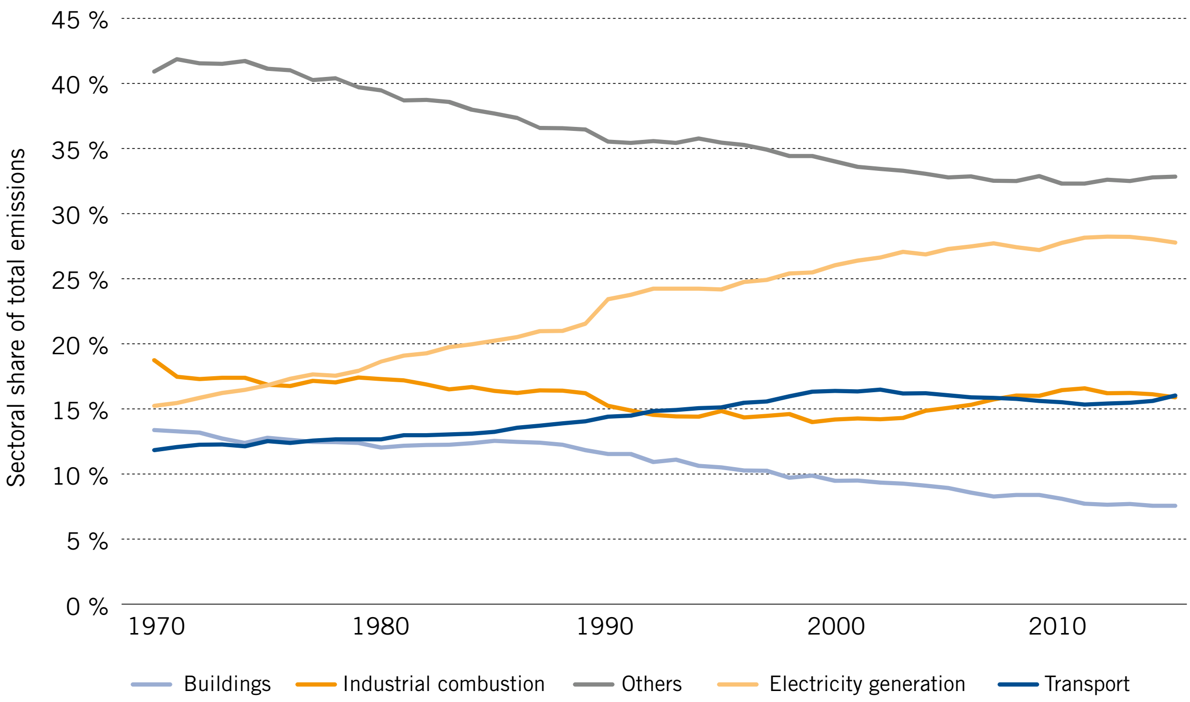



| | |
|---|---|
| Total GHG emissions | 47.7 Gt |
| $CO_2$ emissions | 35.5 Gt |
| Population | 7.51 billion |
| GDP (in USD million) | 80,950,666 |
| Per capita emissions | 1.56 t |




Sources: PIK, EDGAR, World Bank

**Figure 1.4: Sectoral share of total emissions (in percent)**




Globally, the share of GHG emissions from electricity generation has increased significantly since 1970, but has flattened somewhat over the last two decades. Emissions from transport have increased slightly, while emissions from buildings and industrial combustion have reduced their share of total emissions. Other sources of emissions include industrial process emissions, agriculture, and waste.

Source: EDGAR

### Importance of the energy sector

Energy consumption accounts for almost three-quarters of global GHG emissions and includes such activities as electricity generation, heating/cooling, and transport. Another breakdown of GHG emissions by sources (see Figure 1.4) illustrates the significant role a number of other uses of energy play in addition to electricity generation, particularly those that are important for private households.

## › Initial experience with sink projects was gained primarily with forests

Initial experience with sink projects was gained globally through the Clean Development Mechanism (CDM). Over time, this developed into the REDD+[10] mechanism, which is enshrined in the United Nations Framework Convention on Climate Change (UNFCCC). The aim of this is to support developing countries in preserving and developing forests as carbon sinks while taking account of social and ecological factors. A performance-based payment was agreed on in the Warsaw Framework, so the financing of the corresponding climate sinks is now possible.[11] The Paris Agreement confirms the important role of forests as greenhouse gas sinks. However, the precise definition of REDD+ projects, and especially the calculation and recognition of sink performance, are still controversial. According to the Food and Agriculture Organization of the United Nations (FAO),[12] more than 8.66 Gt of sink capacity from 2006 to 2017 had been submitted to the UNFCCC by July 2019, with the lion's share (94 percent) coming from Brazil. It is not considered very likely that this amount will be recognised in total. Nevertheless, the scale of the projects shows that forests can make a significant contribution as sinks.

Forest projects were not accepted under the European Union Emissions Trading Scheme, so significant demand for forest sink projects in Europe came only from voluntary climate action. However, the voluntary market can also absorb a considerable volume. For 2018, *Ecosystem Marketplace*[13] recorded 50.7 Mt $CO_2$eq of offsets from forestry and land use projects. This is relatively low compared to the potential of sink projects, but the further development of carbon credits is guaranteed by the continuity of the market. Buyers, sellers, and certifiers continue to shape the market and the rules for recognition.

10 Reducing Emissions from Deforestation and Forest Degradation.

11 UN-REDD Programme Fact Sheet – About REDD+ (February 2016).

12 FAO, From reference levels to results reporting: REDD+ under the United Nations Framework Convention on Climate Change, Rome, (2019 update).

13 Forest Trends' Ecosystem Marketplace, Financing Emission Reductions for the Future: State of Voluntary Carbon Markets 2019, Washington, D.C.: Forest Trends (2019).

## 1.2 Climate policy in different countries

The COP21 Paris Agreement went into effect on 4 November 2016 after it achieved enough signatures to cross the necessary threshold on 5 October 2016: at least 55 parties to the agreement representing at least 55 percent of global emissions ratified the agreement. By February 2020, this number had increased to 187 out of the 197 parties. Climate neutrality is thus a binding objective under international law, though naturally fraught with the difficulties international law has in terms of its enforceability.[14]

Achieving the COP21 targets is by no means a matter of course. Since 2010, the $CO_2$ intensity related to economic output has been reduced worldwide by 1.8 percent annually. However, in order to implement the agreed COP21 targets in the form of Nationally Determined Contributions (NDC), an annual reduction of $CO_2$ intensity of around 2.5 percent has to be achieved by 2030. Moreover, to realise the agreed goal of keeping global warming below 2 °C, an annual reduction in $CO_2$ intensity of approximately 5 percent is necessary; a tripling of previous $CO_2$ reduction efforts.[15]

At COP25 in Madrid, the Climate Ambition Alliance was formed, which affirms the goal of achieving net zero emissions by 2050. In addition to 73 countries, some 14 regions, 398 cities, 786 companies, and 16 investors have joined this alliance. This shows that climate neutrality is a clear goal for many stakeholders in the private sector, and that pathways to climate neutrality are defined at the local and regional levels in the public sector.

Countries announce their climate protection targets in the submitted Nationally Determined Contributions. At the present time, the targets for 2030 are to be specified, which will be updated in 2021 within the framework of COP26. Worldwide, emissions are likely to increase by 2030, which means that very ambitious reductions of GHGs and even greater use of GHG sinks can be expected after 2030. This gives us a first impression of the challenges countries face when trying to achieve climate neutrality (see Table 1.1).[16]

### The importance of climate protection in energy policy

Climate protection is accorded different levels of importance in the various national energy policies. As illustrated in Figure 1.5, countries can be assigned to four archetypes. For the “green pioneer”, the decarbonisation of the economy is the priority, which is to be achieved through

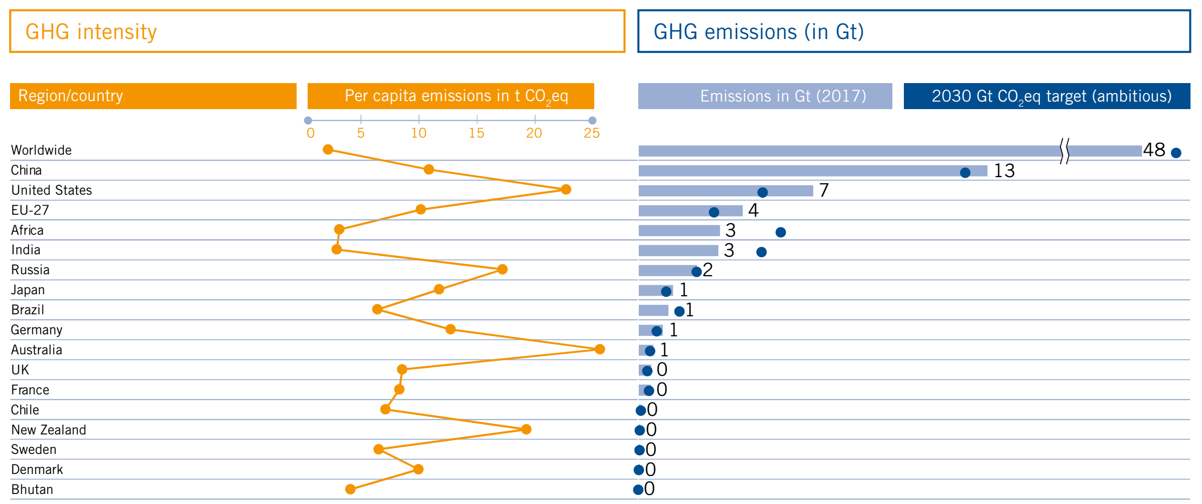
14 G. Hafner, Völkerrechtliche Grenzen und Wirksamkeit von Sanktionen gegen Völkerrechtssubjekte, Zeitschrift für ausländisches öffentliches Recht und Völkerrecht, Vol. 76, pp. 391-413 (2016).

15 Based on global GDP and energy-related $CO_2$ emissions in IEA WEO 2019.

16 UNEP DTU, as at 1 December 2019. India and China have chosen relative rather than absolute emission targets, so the “current policy” data from the Climate Action tracker was used.

17 Joergen Fenhann, Pledge Pipeline, UNEP DTU Partnership (1 December 2019)

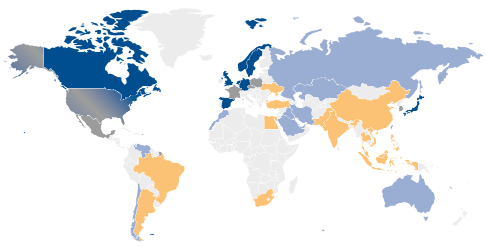
**Table 1.1: Overview of selected countries[17]**




Sources: PIK, World Bank, UNEP DTU

## Figure 1.5: Country grouping according to energy policy

Example countries emit > 85 % of GHG emissions



Archetypes and example countries

| | Green pioneer | Traditionalist | Energy hungry | Energy exporter |
|---|---|---|---|---|
| **Credo** | **Decarbonisation of the economy** | **Cost-efficient energy system** | **Economic growth** | **Energy export** |
| **Goal** | Sustainable energy | Affordable energy | Reliable energy | Exportable energy |
| **Measures** | Strong public interest in reducing/avoiding emissions drives policy<br>· Sector coupling for decarbonisation via the electricity sector<br>· Carbon capture<br>· Storage to integrate a high share of renewable energies | Economic efficiency drives policy<br>· New markets to support existing infrastructure (e.g., capacity markets)<br>· Renewable energies are integrated because of their competitiveness (PV, wind) | Economic growth leads to a strong rise in demand for energy<br>· Security of supply is guaranteed by fossil fuel-fired power plants<br>· Environmental and economic factors drive the integration of renewables (PV, wind) | Countries are dependent on energy exports or have very low costs for renewable generation<br>· Use of natural resources (e.g., oil, high solar radiation, good wind conditions)<br>· Replacing fossil fuels with green energy sources |
| **Examples** |  | | | |

Source: Siemens

sustainable energy production. This policy is driven by strong public interest in reducing or avoiding GHG emissions. Typical measures here include sector coupling with electricity, the capture and storage of $CO_2$ emissions, and the expansion of storage solutions in order to better integrate a high share of renewable energies, especially in the electricity sector.

The “traditionalist” stands in contrast to this. For this archetype, the economic efficiency of the energy system is the main focus, and determines political action. For example, the security of the electricity system is supported by capacity markets. Renewable energies are hardly promoted at all, but are rather in competition with conventional forms of energy generation.

For the “energy hungry” archetype, reliable energy supply is particularly important to enable strong economic growth. Security of supply is often guaranteed by fossil fuels. In addition to economic efficiency, environmental factors such as air pollution are the main focus of the expansion of renewable energies.

For the “energy exporter”, the generation of export surpluses through the sale of energy sources is the focus of policy activities. This is achieved by accessing the country’s natural resource potential. In addition to oil and gas from traditional energy exporters, in future, the cheap availability of renewable energies such as photovoltaics (PV) or wind promises much greater potential.

In the following section, individual countries and regions are analysed in greater detail with regard to their policy approaches.

## EU-27

On 11 December 2019, the European Commission presented the European Green Deal. This contains a catalogue of measures to reduce GHG emissions in all sectors of the economy. With the Green Deal, the Commission is pursuing two targets. The first is to make the EU carbon neutral by 2050. The second target relates to 2030: by then, the EU should reduce its annual GHG emissions by 50 to 55 percent below 1990 levels. So far, a reduction of 40 percent has been achieved. The consequences of extending the target from a 40 percent reduction to 50-55 percent by 2030 are to be examined by autumn 2020. By summer 2021, the targets will be broken down by sector and member state. When presenting the Green Deal in March 2020, Executive Vice President of the European Commission Frans Timmermans (who bears responsibility for climate policy), expressed an optimism that the new technologies will make it possible to remove $CO_2$ from the atmosphere, which is crucial for achieving climate neutrality.

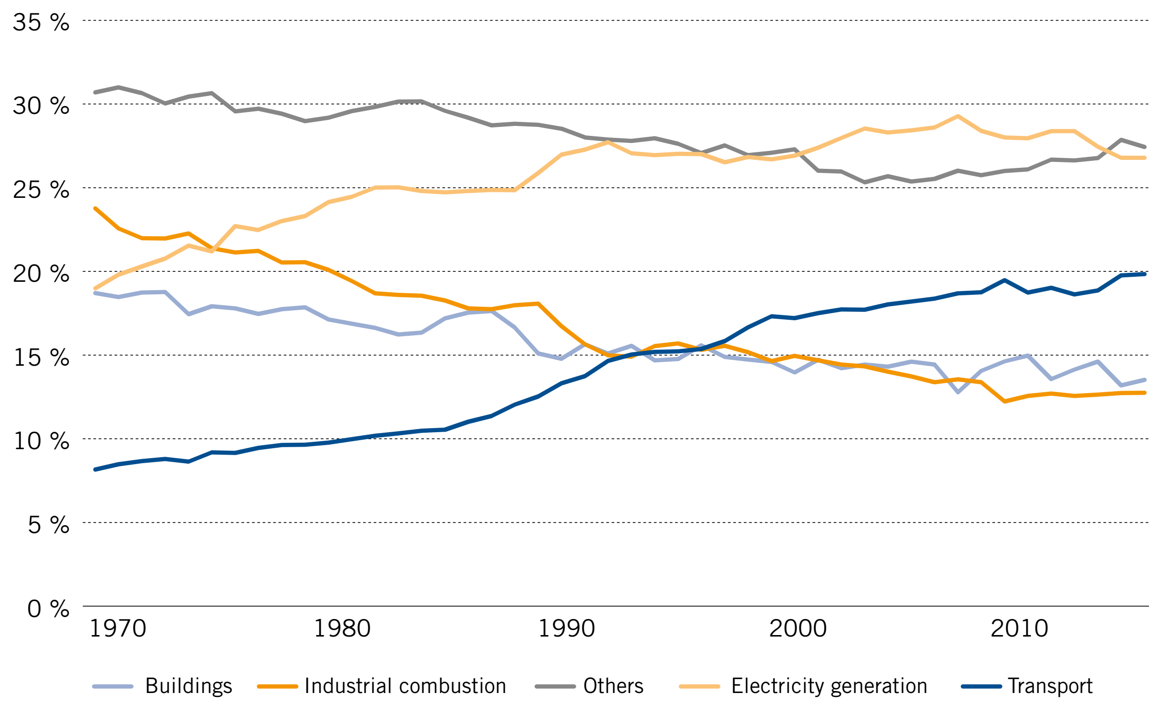
## The Green Deal aims to provide guidelines for a climate-neutral EU

According to the proposals of the European Commission, all sectors should make a contribution to reducing emissions. In the energy sector, the share of renewable energies is to be increased and energy efficiency improved. At the same time, the gas sector is to be decarbonised through the use of renewable or climate-neutral gas. The transport sector is to reduce emissions by 90 percent by 2050. To this end, freight transport is to be increasingly shifted to rail and waterways. The supply of sustainable alternative fuels is to be improved – the EU has set a target of 13 million low-emission vehicles by 2025. Buildings account for around 40 percent of energy consumption in the EU, which is why the EU intends to step up investment in energy efficiency. For industry, the EU sees the strengthening of the circular economy as a central goal, with the initial focus on resource-intensive sectors such as textiles, construction, electronics, and plastics. In particular, the Commission intends to present a proposal to promote the production of $CO_2$-free steel by 2030. The EU wants to direct the agricultural sector through budget funds; in the EU budget for 2021-2027, some 40 percent of the common agricultural policy's overall budget is to contribute to climate protection, and 30 percent of the Maritime Fisheries Fund is to be used to meet climate targets.

The planned decarbonisation of the energy sector also poses a challenge for energy transport infrastructure. In December 2019, the European Network of Transmission System Operators for Electricity (ENTSO-E), and the European Network of Transmission System Operators for Gas (ENTSOG) released the draft of their Ten-Year Network Development Plan (TYNDP) 2020 for public consultation.[18] The requirements of climate neutrality affect the transport of electricity (through the integration of renewable generation) and of gas (e.g., through changed routes of international trade). Depending on the scenario, up to

18 The Ten-Year Network Development Plan (TYNDP) is prepared every two years by ENTSO-E, [https://tyndp.entsoe.eu/].

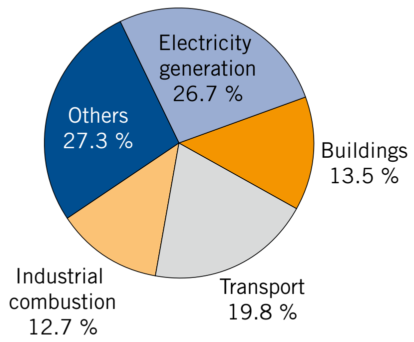
**Figure 1.6: Sectoral share of total emissions in the EU (in percent)**



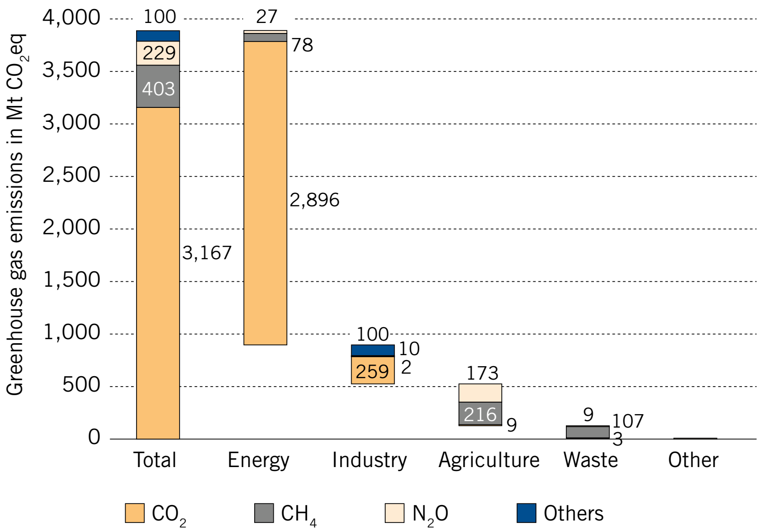

In stark contrast to the global development, in the EU-27, the share of electricity generation in total emissions has declined since the start of EU emissions trading. What is striking is the strong relative growth of the transport sector over a number of years.

Source: EDGAR

**Figure 1.7: Emissions in the EU by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 3,899 Mt |
| $CO_2$ emissions | 3,167 Mt |
| Population | 446.13 million |
| GDP (in USD million) | 14,701,145 |
| Per capita emissions | 8.75 t |
| Share of global emissions | 8.18 % |




In direct comparison to Germany, electricity generation in the EU-27 accounted for a smaller share of emissions in 2017, while transport had a significantly higher share.

Sources: PIK, EDGAR, World Bank

70 percent of the gas consumed in Europe will be imported. This imported gas will be renewable and come, for example, from water electrolysis or bioreactors, or be decarbonised (through CCS or hydrogen produced from methane pyrolysis).

## The EU views NET as part of the solution

Hydrogen plays an important role in the EU's future plans: an alliance for clean hydrogen is to be formed within the framework of the industrial strategy of the European Commission. However, its goals and the detail of its tasks still need to be worked out.[19] The European Commission considers the existing infrastructure to be particularly advantageous for Europe.

The plans of the European Commission to tighten the climate protection targets for 2030 gave rise to major concerns in some member states as early as 2019. Now, some member states, such as the Czech Republic and Poland, have suggested postponing the Green Deal because of the coronavirus crisis. The sharp decline in economic activity that has occurred since spring 2020 due to measures to stop the spread of the virus will certainly not leave the long-term climate targets untouched.

In March 2019, the Innovation Fund was launched, which will provide a total of EUR 10 billion for the development and implementation of climate-friendly technologies in the fields of energy-intensive industry, renewables, energy storage, and CCS. Within the framework of the Horizon 2020 research program, funding of EUR 18.70 million was provided for two industrial CCS projects (including bio-CCS), funding of EUR 2.20 million for a project in the field of geological storage, and funding of EUR 9.79 million for a project dealing with the risks and monitoring of CCS. The successor program to Horizon 2020 – Horizon Europe – is also aimed at promoting technologies and pathways to climate neutrality. For example, one of the five mission areas, as they are known, focuses on climate-neutral and smart cities. This focus is intended to contribute to achieving the goals set by international coalitions, such as COP21 or the United Nations Sustainable Development Goals.[20] As part of the European Green Deal, which was further specified in March 2020, a total

19 European Commission, A New Industrial Strategy for Europe, 10 March 2020.

20 European Commission, Horizon Europe – the next research and innovation framework programme, [https://ec.europa.eu/info/horizon-europe-next-research-and-innovation-framework-programme_en].

of EUR 1 trillion will be invested in sustainable projects over a period of ten years through the Sustainable Europe Investment Plan (SEIP). In this context, the Just Transition Mechanism aims to ensure that all member states benefit from the Green Deal.[21]

The EU is dealing with the topic of climate change on an ongoing basis, which offers opportunities for steady improvement. In order to achieve the climate targets, it is crucial to propose an ambitious but realistic pathway. Postponing investments to a later period in time leads to increasing overall costs.[22] Conversely, over-ambitious pathways lead not only to high investment costs over a short period of time – they also miss the opportunity to benefit from the learning curves of the technologies.

**Summary:** The European Commission has ambitious climate targets. Extensive funding flows into the research and development of climate protection technologies. However, diverging national interests within the EU and the embedding of climate protection policy in the global context present a challenge.

21 European Commission, The European Green Deal Investment Plan and Just Transition Mechanism explained, [https://ec.europa.eu/commission/presscorner/detail/en/qanda_20_24].

22 Eurelectric, Power Choices Reloaded (2013).

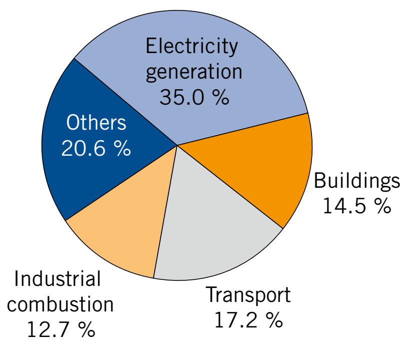
## Germany

In 2016, Germany adopted the Climate Action Plan 2050 *(Klimaschutzplan 2050)*, which confirms the emissions pathway of the German federal government's energy strategy *(Energiekonzept)*. The goal is to be practically GHG-neutral in 2050, with an emission reduction of between 80 to 95 percent compared to 1990. However, there is still a gap between this and the target agreed in Paris, meaning that the energy strategy, which has already been supplemented since 2010 with the phase out of nuclear energy and coal, needs to be further amended. The German Federal Climate Change Act (*Klimaschutzgesetz,* KSG) of December 2019 confirms the target of greenhouse gas neutrality.

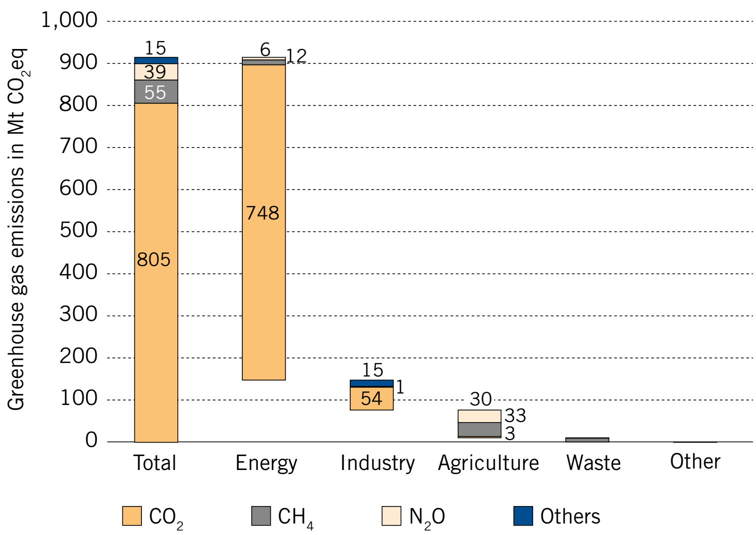
> **Germany's Climate Action Plan of 2016 aims for an emission reduction of between 80 and 90 %**

For the energy industry, the expansion of renewable energies and the phasing out of coal are expected to reduce emissions by over 61 percent compared to 1990. By 2030, the industrial sector is expected to reduce its emissions by at least 49 percent on 1990 levels. This is to be

**Figure 1.8: Emissions in Germany by source and greenhouse gas (2017)**



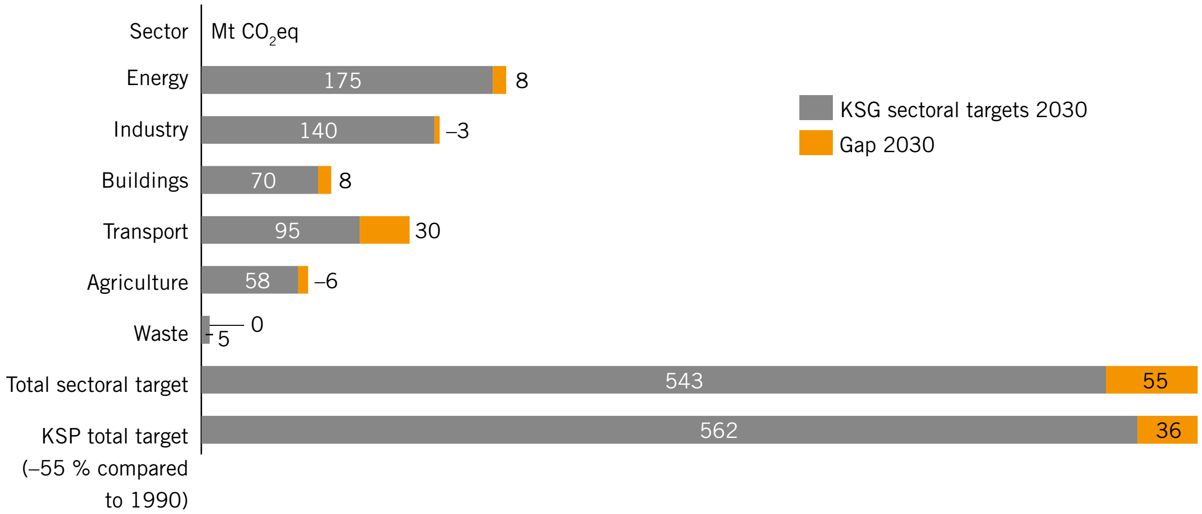

| | |
|---|---|
| Total GHG emissions | 915 Mt |
| $CO_2$ emissions | 805 Mt |
| Population | 82.56 million |
| GDP (in USD million) | 3,656,749 |
| Per capita emissions | 11.06 t |
| Share of global emissions | 1.92 % |




Electricity generation in Germany has a relatively high share of emissions compared with other countries.

Sources: PIK, EDGAR, World Bank

**Figure 1.9: Comparison of the sectoral targets of the German Federal Climate Change Act (KSG) with the German Climate Protection Program 2030 scenario (KSP)**




The largest gaps are in the transport, buildings, and agricultural sectors. Source: Prognos

achieved through research that is open to various technologies, and where carbon capture, utilisation, and storage (CCUS)[23] is also to play an important role. Particular attention will be paid to the buildings sector, as the infrastructure here is very long-lasting. For this reason, the reduction is planned to be at least 66 percent by 2030 – as a first step towards an almost climate-neutral building stock by 2050. This will be achieved through new building standards and renovation strategies for existing buildings. In particular, fossil fuel-fired heating systems need to be replaced by renewable solutions. Emissions are to be reduced by at least 40 percent in the transport sector, which is to be achieved through sector coupling (i.e., electromobility and other alternative drive systems). Greater use of public transport is also aspired to. In agriculture (where the target is a minimum 31 percent reduction), the climate strategy primarily envisages a reduction in nitrous oxide emissions through decreased fertilisation, but considers the potential reductions to be fundamentally limited in this sector.

According to a study by Prognos on behalf of the German Federal Ministry for Economic Affairs and Energy (Bundesministerium für Wirtschaft und Energie, BMWi), Germany will not achieve the 2030 targets without additional measures.[24] In the scenario where the German Climate Protection Program 2030 (*Klimaschutzprogramm 2030,* KSP) is applied, a reduction of 52.2 percent is achieved instead of the targeted 55 percent. Here, the failure to meet the targets is most evident with respect to transport, buildings, and agriculture. The study concludes: “Achievement of the overall target still seems possible if further measures are adopted in addition to the Climate Protection Program.” However, even achieving the targets in the Climate Protection Program scenario is not assured, and requires effort from all stakeholders.

The hydrogen strategy plays a special role in achieving climate neutrality. By means of hydrogen produced from renewable energy and its subsequent processing into synfuels (where it can be enriched using captured $CO_2$), fossil carbon use can be gradually reduced in both the industrial sector (e.g., steel and chemicals) and private households (e.g., mobility and heating). The hydrogen strategy is thus a key building block for the realisation of sector coupling – with the advantage that the existing infrastructure for liquid and gaseous fuels can continue to be used in part. This should not be underestimated in view of the many challenges facing the expansion of infrastructure in Germany. For example, the GET H2 Nukleus project (involving BP, Evonik, Nowega, OGE, and

23 CCUS is the capture of carbon dioxide in industrial processes and its use for further industrial processes.

24 Prognos, Energiewirtschaftliche Projektionen und Folgeabschätzungen 2030/2050 (10 March 2020).

RWE Generation) aims to develop a publicly accessible network for green hydrogen in North Rhine-Westphalia and Lower Saxony by 2022 using existing pipelines from Nowega and OGE. Within the German federal government, however, there are differing views regarding which areas green hydrogen should be given priority to as an energy source and raw material.

In further updates to the Climate Action Plan 2050, Germany needs to clarify in detail how climate neutrality can be achieved. The focus of the previous climate strategy was on the reduction GHG emissions. The German government's use of GHG sinks has concentrated mainly on forests. However, the Climate Action Plan is open to a variety of technologies, and there is room or even the need for technologies with negative emissions. In its special report, the German Council of Economic Experts (Sachverständigenrat zur Begutachtung der gesamtwirtschaftlichen Entwicklung) emphasises: "The need for negative emissions increases as the temperature targets to be achieved become more ambitious and as policy measures to reduce greenhouse gas emissions are postponed further into the future."[25] Experts are critical of strongly restricted competition due to a lack of openness to a variety of technologies (e.g., in the transport sector).[26]

The BMWi`s project funding for climate-neutral technologies in Germany focuses on renewable energies (EUR 179.44 million) and energy efficiency (EUR 122.93 million). In the field of basic technologies for negative emissions technologies, the focus is on CCUS projects such as Carbon2Chem (EUR 16.90 million).[27]

**Summary:** Germany has placed increasing focus on climate protection since 2010, but has no long-term plans for nuclear energy and, as yet, none for CCS. Due to the expansion of renewables and the phasing out of coal, $CO_2$ emissions in the electricity sector are expected to be reduced by over 60 percent by 2030. Reducing GHG emissions in the buildings and transport sectors remains a challenge. The use of hydrogen is increasingly viewed as key to a climate-neutral economy.

25 German Council of Economic Experts, Setting Out for a New Climate Policy, Ausschussdrucksache Bundestag 19(26)41-1 (2019).

26 Agora Verkehrswende, Technologieneutralität im Kontext der Verkehrswende. Kritische Beleuchtung eines Postulats (2020).

27 BMWi, 2019 Federal Government Report on Energy Research (figures for 2019).

## Sweden

At end of 2017, Sweden adopted a new climate policy framework, consisting of a climate act, climate targets, and the establishment of a climate policy council. Sweden intends to stop net GHG emissions by 2045 at the latest. The package was adopted by the Swedish parliament with a broad majority. The Climate Act came into effect on 1 January 2018. It provides for the government to submit an annual climate change report as part of the draft budget. In addition, a climate policy action plan is to be drawn up every four years in which the government describes how the climate targets are to be achieved. The link to the budget is intended to ensure that climate policy and the federal budget can be reconciled.

Emissions are to be 85 percent lower by 2045 at the latest, with the remaining 15 percent to be provided by GHG reductions outside of Sweden. After 2045, Sweden even wants to achieve a negative emissions balance. Sweden is pursuing an approach that is open to various technologies; in addition to the increased use of forest as sinks, BECCS is also considered an option.

The Swedish Climate Act is aimed primarily at emissions not covered by the European Union Emissions Trading Scheme. The target pathway for emissions falls under the EU Effort Sharing Regulation, using 1990 as the reference year:

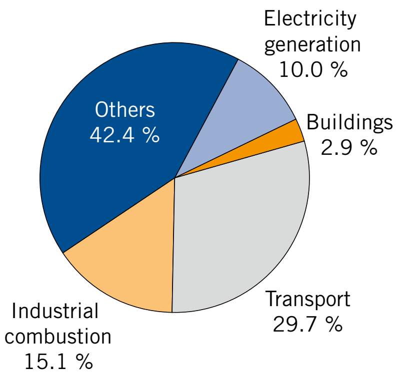
- 2020: emissions 40 percent lower;
- 2030: emissions 63 percent lower;
- 2040: emissions 75 percent lower.

These targets can also be met partly through measures taken outside of Sweden.

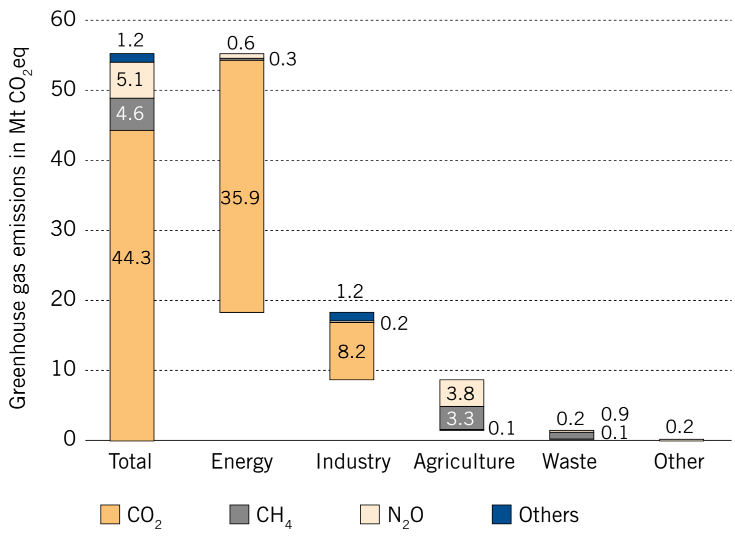
By 2030, emissions from domestic transport should be reduced by at least 70 percent from 2010 levels. Domestic flights are not included here, as they are subject to EU emissions trading. A climate policy council has been established to increase public acceptance of all necessary measures. The council consists of members from the fields of climate research, climate policy, and the social and behavioural sciences. Every year, a progress report is submitted to the government, which evaluates the government's climate policy action plan.[28] These reports consider the measures introduced thus far to be insufficient, as they would lower the estimated GHG emissions in 2045 by only 31 to 41 percent. In the non-ETS sectors,

28 Swedish Climate Policy Council, 2019 Report of the Swedish Climate Policy Council.

## Figure 1.10: Emissions in Sweden by source and greenhouse gas (2017)



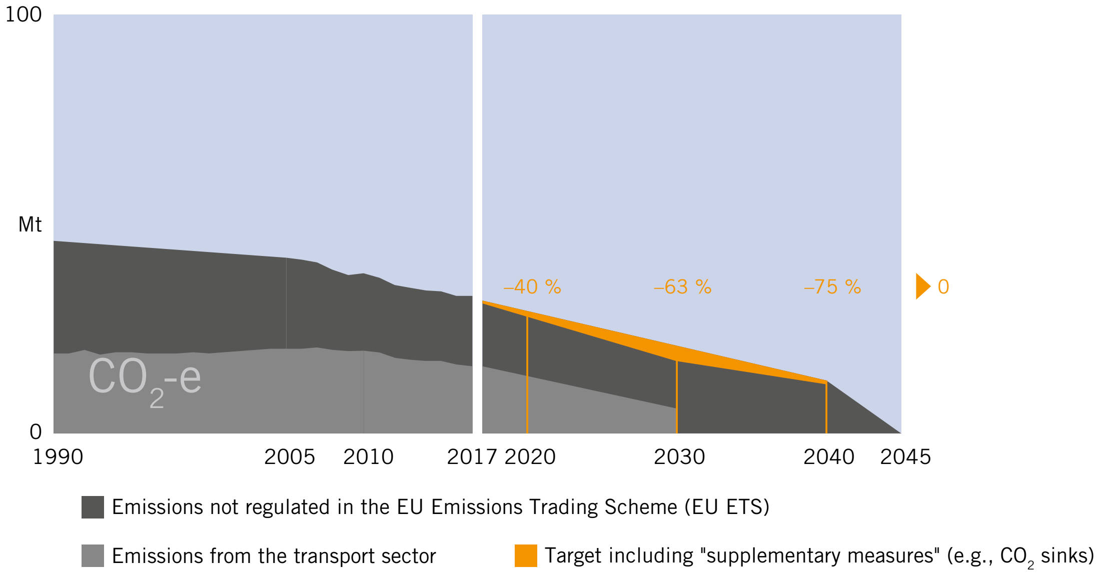

| | |
|---|---|
| Total GHG emissions | 55.17 Mt |
| $CO_2$ emissions | 44.27 Mt |
| Population | 10.18 million |
| GDP (in USD million) | 556,086.49 |
| Per capita emissions | 5.49 t |
| Share of global emissions | 0.12 % |




Sweden has very low emissions in electricity generation due to its nuclear and hydroelectric power sources. Transport accounted for around a third of emissions in 2017. The low emissions in the buildings sector are mainly due to the widespread use of heat pumps.

Source: PIK, EDGAR, World Bank

## Figure 1.11: The Swedish GHG emission pathway to climate neutrality in 2045 (in Mt $CO_2$eq)




Source: Swedish Environmental Protection Agency transport was mentioned as the most critical area, as well as the lack of international regulations for the recognition of reduction measures outside of Sweden.

## Sweden aims to be climate neutral by 2045 at the latest

Within the framework of the Nordic Council, Finland, Sweden, Norway, Denmark, and Iceland have signed a declaration in which they agree to ambitious climate targets, which also include the further development and application of CCS.[29] Research projects in this area are investigating, among other things, the pipeline transport of $CO_2$ from Sweden to existing $CO_2$ storage facilities in Norway. In Sweden, CCS is considered an essential technology for dealing with industrial emissions, such as in cement production.[30]

29 Declaration on Nordic Carbon Neutrality. Summit in Helsinki, Finland, on 25 January 2019.

30 Sofia Klugman et al., A climate neutral Swedish industry – An inventory of technologies, IVL Swedish Environmental Research Institute (December 2019); examples of hydrogen projects in Sweden: HYBRIT (steel) and CEMZERO (cement).

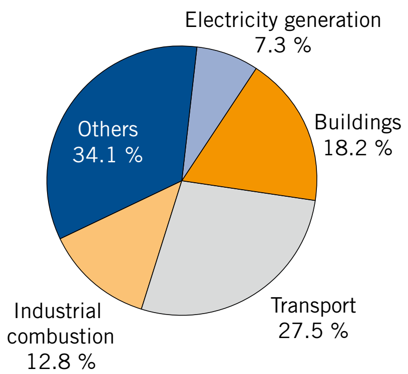
**Summary:** Sweden is pursuing ambitious climate targets that are intended to be achieved with GHG sinks outside of the country. The measures taken so far at not yet sufficient to achieve the climate targets. Sweden is cooperating with its neighbouring countries in the research and development of CCS.

### France

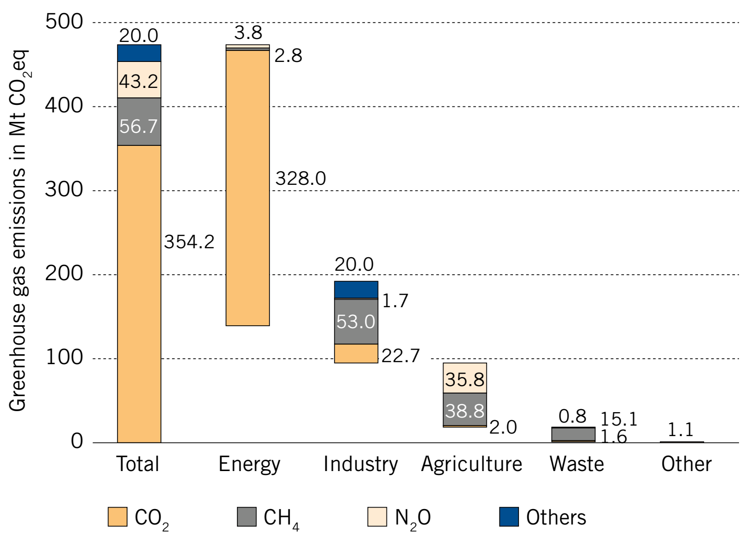
In November 2019, Law n° 2019-1147 on Energy and the Climate[31] was passed. France has the target of becoming $CO_2$-neutral by 2050 at the latest. To achieve this, the consumption of fossil fuels is to be reduced by 40 percent by 2030, and the phasing out of coal in energy generation is to be completed by 2022. In addition, the share of nuclear energy in the electricity mix is to be reduced to 50 percent by 2035. Originally this target was to be reached by 2025, but under President Emmanuel Macron, the parliament extended the transition period to 2035. Since then, the French government has announced its plans to build new nuclear power plants as part of the solution to achieving climate neutrality.

31 LOI n° 2019-1147 du 8 novembre 2019 relative à l'énergie et au -climat.

**Figure 1.12: Emissions in France by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 449.74 Mt |
| $CO_2$ emissions | 323.28 Mt |
| Population | 66.99 million |
| GDP (in USD million) | 2,777,535.24 |
| Per capita emissions | 7.09 t |
| Share of global emissions | 0.99 % |




France has relatively high emissions from the buildings and transport sectors. Source: PIK, EDGAR, World Bank

## France plans to ban the sale of cars using fossil fuels by 2040

The expansion of renewable energy is to be stepped up – the target of a 33 percent share of renewable energy in energy consumption was set at the end of 2019 – and energy efficiency measures for residential buildings are also intended to help reduce heating consumption. This is to be achieved by energy consumption labelling and setting minimum standards. Similarly, certain buildings, such as supermarkets, will be obliged to use solar panels in new buildings. The sale of cars that use fossil fuels is to be banned from 2040.

**Summary:** In addition to the expansion of renewable energies and minimum standards for energy efficiency, France is also pursuing its climate targets through technology bans and the phasing out of coal-fired power. The role of nuclear energy in France remains uncertain. France wants to become $CO_2$-neutral by 2050.

### Denmark

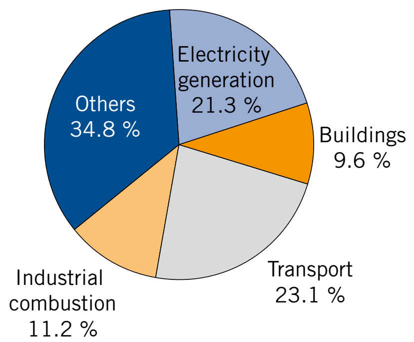
In 2019, the Danish parliament passed a climate law with the aim of reducing emissions by 70 percent from 1990 levels by 2030. The law aims to achieve $CO_2$-neutrality by 2050. As of 2020, new legally-binding targets with a ten-year outlook will be set every five years.

The government has to submit an annual report on the international impact of Danish climate protection measures and on the impact of Danish imports and consumption. It also has to present a strategy on how its foreign, development, and trade policies will promote international climate protection measures. A climate council will assess progress on an annual basis, and make recommendations for further measures.

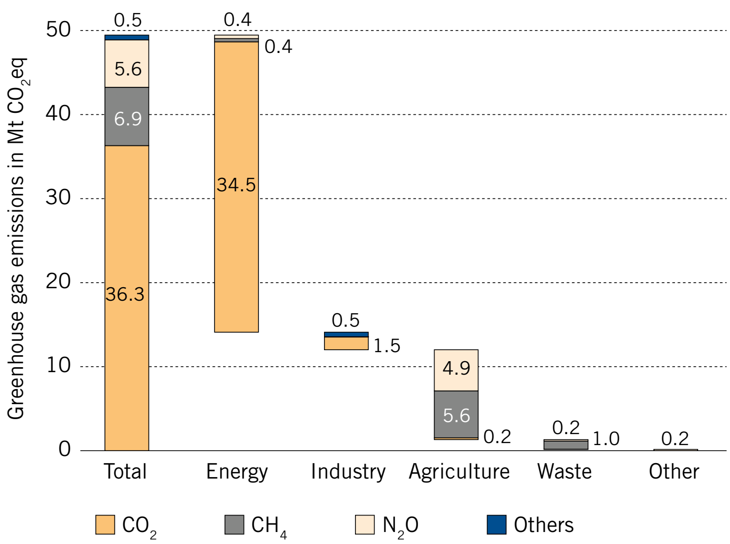
In the transport sector, the sale of petrol and diesel-powered vehicles will be prohibited from 2030. From 2020, all buses in public transport have to be $CO_2$-neutral and, from 2030, they will no longer be permitted to emit $CO_2$ or air-polluting particles.

In the buildings sector, wood-burning stoves installed before 2000 have to be replaced when the property they are in is purchased.

**Figure 1.13: Emissions in Denmark by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 49.39 Mt |
| $CO_2$ emissions | 36.27 Mt |
| Population | 5.76 million |
| GDP (in USD million) | 329,417.07 |
| Per capita emissions | 8.57 t |
| Share of global emissions | 0.10 % |




Denmark has relatively high emissions from the agricultural sector. In contrast to Sweden, the high emissions from electricity generation are particularly striking.

Sources: PIK, EDGAR, World Bank

## Denmark will ban the sale of petrol and diesel-powered vehicles by 2030

Denmark is concentrating on forests for its $CO_2$ sinks. Research will promote the development and usage of new climate-friendly methods in the agricultural sector. BECCS will also play an important role, and biogas plants will be sealed to ensure that no methane is emitted into the atmosphere.

**Summary:** Denmark is pursuing ambitious climate protection targets and measures. Technology bans feature among the measures to be introduced in attempting to achieve the targets.

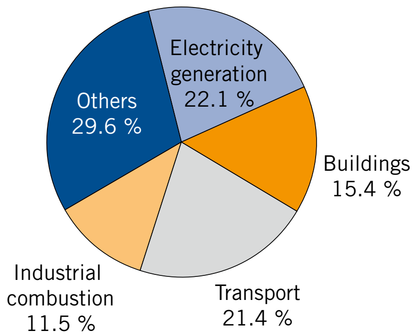
### United Kingdom

In 2019, the UK adopted legislation to bring all GHGs to net zero by 2050 at the latest. The UK also intends to use GHG sinks to achieve this, such as afforestation and CCS. Parallel to this, in September 2019, Scotland made the decision to become climate neutral five years earlier (in 2045) as part of the Climate Change Bill. As an intermediate step, Scotland wants to achieve a 75 percent reduction in GHG emissions by 2030.

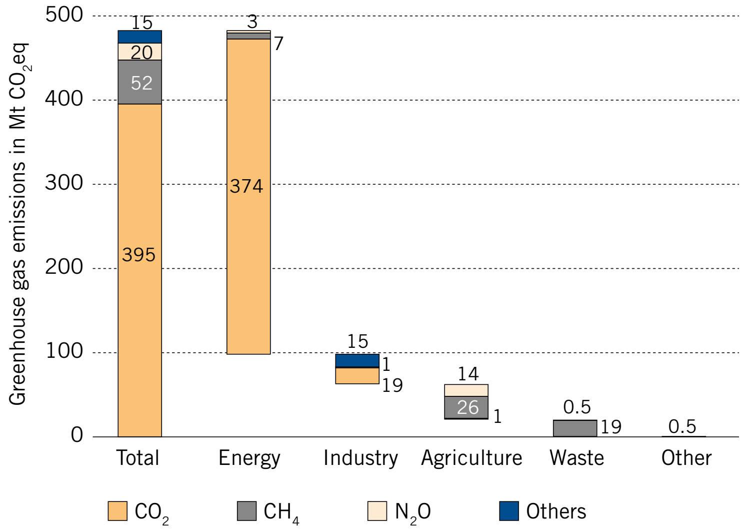
To implement a substantial reduction in GHG emissions, the UK is estimated to need technologies that can remove 130 Mt $CO_2$ per year by 2050.[32] This is to be achieved by a variety of methods, including forest management, soil carbon sequestration, and CCS. For the latter, the 75 Mt $CO_2$ per year contribution made by BECCS and DACCS is expected to cover more than half the required reduction.

32 The Royal Society & Royal Academy of Engineering, Greenhouse Gas Removal (September 2018)

**Figure 1.14: Emissions in the United Kingdom by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 482.00 Mt |
| $CO_2$ emissions | 383.50 Mt |
| Population | 66.06 million |
| GDP (in USD million) | 2,666,229.18 |
| Per capita emissions | 7.30 t |
| Share of global emissions | 1.01 |




The United Kingdom expects that, of the current GHG emissions of around 480 Mt $CO_2$eq, a base of 130 Mt $CO_2$eq of remains to be addressed with negative emissions technologies.

Sources: PIK, EDGAR, World Bank

To achieve this, CCS is to be funded with GBP 800 million in the coming years.[33] Much of the funding is expected to go to the Humber River, Merseyside, Teesside, Runcorn, and Grangemouth industrial clusters. Drax, a power plant operator in the Humber region, has already proposed BECCS as a solution, and is optimistic that a biomass power plant will be able to capture around 10,000 tons of $CO_2$ per year in the next five to seven years. Strategically, these plans are embedded in the long-term plan to make the UK a leading technology provider in CCUS.[34]

## The UK aims to be climate neutral by 2050, Scotland as early as 2045

Parallel to this, the United Kingdom aims to achieve 40 GW of offshore wind capacity in electricity generation by 2030. Floating platforms are to be promoted for this purpose. There is around 10 GW of wind capacity installed offshore, and another 4 GW are in planning or under construction.

A measure that will be more noticed by private households is England's plans to bring forward an end to the sale of petrol, diesel, and hybrid vehicles from 2040 to 2035. In addition, the Scottish government has pledged to phase out the need for new petrol or diesel cars by 2032. Thus far, the solution presented in the UK has not been open to a variety of technologies; only electric vehicles are considered to be zero-emission vehicles.

**Summary:** The UK is pursuing the goal of climate neutrality by 2050, mainly by expanding renewables and banning certain technologies. Negative emissions are included in the ambitious targets. At the same time, the country is positioning itself as the world's leading supplier of CCUS technology in combination with biomass power plants.

33 M. Carr et al., Britain Is Getting Ready to Scale Up Negative-Emissions Technology, Bloomberg (7 February 2020).

34 BEIS, Clean Growth – The UK Carbon Capture Usage and Storage deployment pathway (2018).

### Switzerland

Under the Paris Agreement, Switzerland has committed to halving its GHG emissions by 2030 (from the reference year of 1990). Switzerland's original target of reducing GHG emissions between 70 to 85 percent by 2050 was tightened in June 2019; by 2050 at the latest, Switzerland plans to emit no more GHG than it can absorb from natural and technological carbon sinks.[35]

## Switzerland plans to be climate neutral by 2050

Switzerland is initially focusing on the reduction of energy-related GHG emissions in transport, buildings, and industry through the use of existing technical solutions. The unavoidable base of emissions that cannot be altered by technological progress or behavioural changes is to be addressed through the use of negative emissions technologies. Switzerland has left it open as to whether these technologies will be used in Switzerland or used outside of Switzerland and credited to the Swiss targets.

The Swiss Federal Office for the Environment (FOEN) has provided a rough estimate of emissions that will be difficult to avoid in 2050:

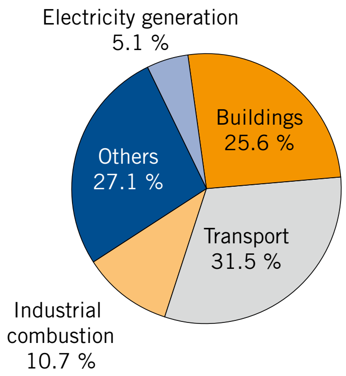
- cement production: around 2 Mt $CO_2$eq per year;
- waste (waste incineration and other elements of the waste sector): 3-3.5 Mt $CO_2$eq per year; and
- agriculture/food production: around 4.8 Mt $CO_2$eq per year.

CCUS is regarded as the solution for industry, while other negative emissions technologies are foreseen for agriculture. The upper limit of Switzerland's theoretical storage potential is estimated at 6 Mt $CO_2$ per year, so Switzerland will have difficulty reaching its targets without international activities or additional technological solutions.

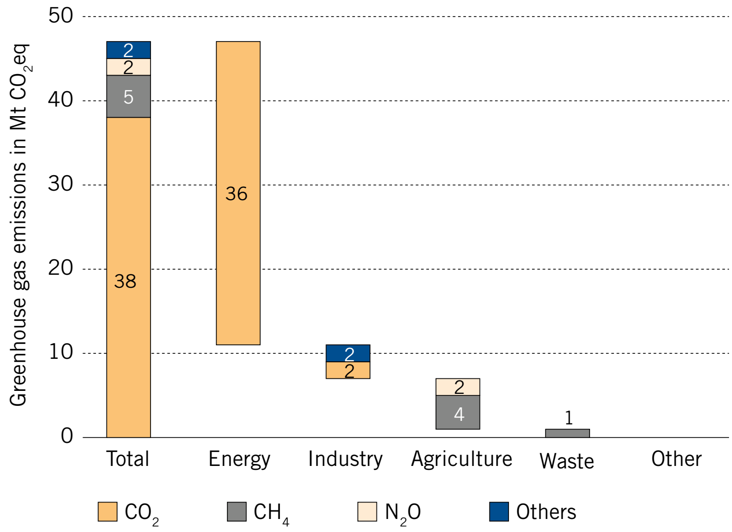
Air traffic plays a special role. According to the territorial principle, emissions from international air traffic and international shipping are currently not included in a country's reduction targets. Flights within Switzerland and the European Economic Area have so far been covered by the European Union Emissions Trading Scheme. However, if all flights are to be included in future – which is unavoidable if global climate neutrality is to be achieved –

35 Federal Office for the Environment FOEN, Climate Target 2050: Net zero greenhouse gas emissions (26 February 2020).

**Figure 1.15: Emissions in Switzerland by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 47.20 Mt |
| $CO_2$ emissions | 38.20 Mt |
| Population | 8.45 million |
| GDP (in USD million) | 679,950.92 |
| Per capita emissions | 5.58 t |
| Share of global emissions | 0.10 % |




Switzerland has a relatively high share of emissions from the transport and buildings sectors.

Sources: PIK, EDGAR, World Bank

FOEN expects at least another 5.4 Mt $CO_2$eq per year that will have to be offset.

**Summary:** Switzerland is pursuing its goal of climate neutrality by 2050 through the use of existing climate technologies. However, the Swiss Federal Office for the Environment sees the need for negative emissions technologies, such as CCUS, in various sectors of the economy that are difficult to decarbonise.

## United States

On 4 November 2019, the United States officially announced its withdrawal from the Paris Agreement, which will take legal effect in November 2020. At the same time, however, the U.S. government reaffirmed its commitment to reducing emissions. There is local resistance to the withdrawal from the climate agreement; the three states of California, Hawaii, and New York belong to the Climate Ambition Alliance, as do several cities, including Austin, Dallas, Houston, and Washington, D.C. Various companies are also among the signatories, such as Hewlett Packard, Levi Strauss, Nike, and NRG Energy.

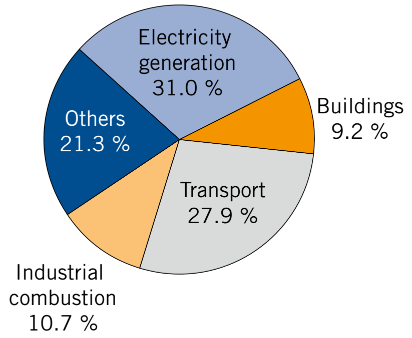
### In 2019, the United States withdrew from the Paris Agreement

Accordingly, the future pathway of the United States in relation to climate neutrality will be characterised by regional and local initiatives. Here, regulations in one state can be adopted by other states over time. One example is the Low Emission Vehicle (LEV) standards developed in California. These have been adopted by 13 other states thus far, and their introduction is being discussed in six further states. As California is considered a pioneer in the United States in environmental issues, it is worth taking a closer look at the state.

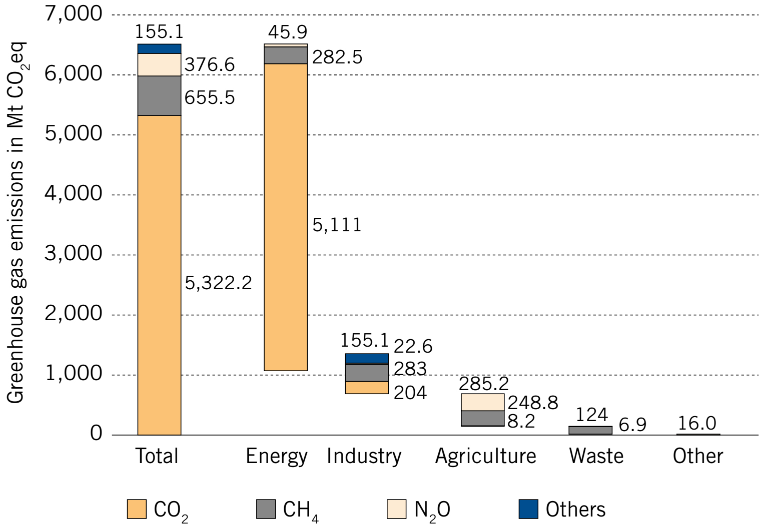
California's original target of an 80 percent reduction by 2050 was tightened in 2018. A law was passed with the target of 100 percent $CO_2$-free electricity generation by 2045, as was an Executive Order with the aim of a climate-neutral California by 2045 (although this has more the character of a decree, and is not legally binding). As such, California's pathway is not defined by a single law, but by a series of different measures.

In early 2020, the Lawrence Livermore National Laboratory (primarily funded by the U.S. Department of Energy)

## Figure 1.16: Emissions in the United States by source and greenhouse gas (2017)




| | |
|---|---|
| Total GHG emissions | 6,509 Mt |
| $CO_2$ emissions | 5,322 Mt |
| Population | 325.15 million |
| GDP (in USD million) | 19,485,394 |
| Per capita emissions | 20.02 t |
| Share of global emissions | 13.65 % |




In 2017, the United States recorded a relatively high share of emissions from transport in comparison to other countries.

Sources: PIK, EDGAR, World Bank

presented the *Getting to Neutral: Options for Negative Carbon Emissions in California* study, which outlines the way forward for the state. According to the study, California will likely need to remove 125 Mt $CO_2$ per year from the atmosphere. The study only considers measures to be implemented in California, estimating the costs to be somewhat less than 0.4 percent of the state's annual GDP. The study recommends three pillars to achieve climate neutrality: 25 Mt $CO_2$ could be absorbed annually through better management of natural and working lands; 84 Mt $CO_2$ through the conversion of waste biomass, and 16 Mt $CO_2$ through DACCS. DACCS will also be used to compensate for the effects of other GHGs, especially methane and nitrous oxide.

## California has introduced legislation for zero-emission vehicles and zero-emission buildings

California's legislation has aimed at reducing emissions from road traffic since 1990 by means of the Zero Emission Vehicle program. While this reduction was initially a measure to combat smog in some Californian cities, climate protection was soon added as another motivation for the legislation. According to the legislation, there should be five million zero-emission vehicles by 2030, and 250,000 charging stations for electric vehicles in California by 2025.

For the buildings sector, the Zero-Emissions Buildings and Sources of Heat Energy Bill requires all new buildings constructed from 2030 to be zero-emissions buildings. It also stipulates that a strategy should be developed to achieve a 40 percent reduction in emissions from the building stock in 2030 in comparison to the reference year of 1990.

An analysis by the Climate Action Tracker[36] predicts that the sum of all regional targets in the United States is within striking distance of the original U.S. target for 2025 – however, this is not considered particularly ambitious. Both the Climate Action Tracker and the EIA[37] expect that U.S. emissions will move sideways or even rise moderately in the decade to 2030. So far, 22 states, 550 cities, and 900 companies have made climate commitments. Through these programs (e.g., for the expansion of re-

36 [https://climateactiontracker.org/countries/usa/] (as at 25 March 2020).

37 EIA Annual Energy Outlook 2020 (29 January 2020), [https://www.eia.gov/outlooks/aeo/].

newable energies), all U.S. states contribute to a greater or lesser extent to climate protection.

Significant reductions in $CO_2$ emissions have been recorded in the electricity sector in the United States. According to the IEA,[38] they have fallen by over 25 percent since 2000, despite a 10 percent increase in electricity consumption. This is due to a transformation in power generation driven by low gas prices. Coal-fired power generation still accounted for more than 50 percent of the electricity mix in 2000, but this figure was below 30 percent in 2018. In contrast, the share of natural gas in electricity generation doubled during the same period, rising from 16 percent to far over 30 percent.

Research activities in the United States are heavily funded. According to Sanchez et al.,[39] some USD 7 billion has been invested in CCS research (in basic research and technology development) by the United States Department of Energy (DOE) since 2008. Biorefineries account for around three-quarters of the projects implemented. In March 2020, the DOE and the National Energy Technology Laboratory (NETL) announced that they would provide up to USD 22 million for research into direct air capture technologies.[40]

Enhanced oil recovery (EOR) is a driving force behind CCS in the United States. In this process, $CO_2$ from coal-fired power plants is injected into the ground to achieve higher production rates from existing oil fields. The main driver for these projects is tax credits; permanently stored $CO_2$ receives a credit of USD 50/t, and $CO_2$ used for EOR receives a credit of USD 35/t.[41] The Petra Nova project in Texas captures 5,000 t $CO_2$ per day and transports it to an oil field via an 80-mile pipeline, which has resulted in an increase in production from 300 to 4,000 barrels per day. Despite the production of oil, on balance there are negative emissions, as the additional production of 3,700 barrels corresponds to around 1,850 t $CO_2$ – much less than the 5,000 t $CO_2$ captured in the process. More important, however, is the demonstration that the industrial capture and transport of $CO_2$ can work at scale. However, other calculations shows that EOR usually does not lead to negative emissions, but rather reduces specific emissions of crude oil by around 10 percent, from 500 kg $CO_2$/bbl to 438 kg $CO_2$/bbl.[42]

**Summary:** Although the United States has withdrawn from the Paris Agreement, individual U.S. states continue to push climate protection forward through their own targets, standards, and accession to international agreements. The market situation also influences $CO_2$ emissions in the United States: in the electricity sector, for example, emissions fell due to the competitive advantages of natural gas over coal. Research in the field of climate protection technologies such as CCS is being extensively pursued.

## Japan

In June 2019, the Japanese government announced plans for the country to be climate-neutral by 2050 at the latest. The previous goal was to reduce emissions by 80 percent by 2050 (compared to the reference year of 2010). Japan views hydrogen technologies as well as the capture (CCS) and usage of $CO_2$ (CCUS) as the focal points for innovation in achieving this goal. The aim is to make CCUS economically viable by 2023 and CCS by 2030, and to reduce the production costs of hydrogen by more than 90 percent by 2050.

In March 2020, the Japanese government decided to leave the climate target for 2030 at its previous level of a 26 percent reduction from the reference year of 2013.

> Japan wants to keep coal in its electricity mix and make it climate neutral with CCS

As Japan continues to see a role for coal and gas as major contributors to the electricity mix alongside renewables, the focus on CCS is understandable. JX Nippon Oil is also involved in the previously-mentioned Petra Nova project in Texas in order to gain experience with the technology. Japan is highly dependent on energy imports, which cover around 94 percent of primary energy consumption. Since the expansion of renewable energies is very difficult for geographical reasons, Japan is focusing on coal and

38 IEA Electricity Information 2019 & $CO_2$-Emissions 2019 from Fuel Combustion, [https://www.iea.org/countries/united-states].

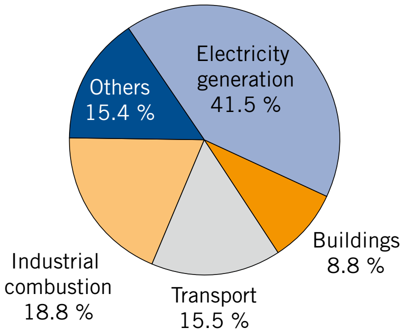
39 Daniel L Sanchez et al., Federal research, development, and demonstration priorities for carbon dioxide removal in the United States, Environmental Research Letters, Vol.13, No.1 (2018)

40 NETL, Department of energy to provide $22 million for research on capturing carbon dioxide from air, [https://www.netl.doe.gov/node/9636].

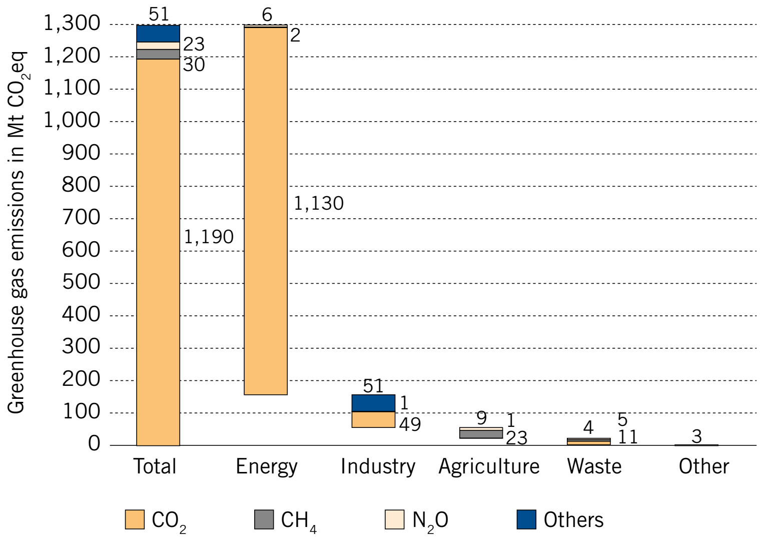
41 Clean Air Task Force, The Role of 45Q Carbon Capture Incentives in Reducing Carbon Dioxide Emissions (2017)

42 Nicholas A. Azzolina et al., How green is my oil? A detailed look at greenhouse gas accounting for $CO_2$-enhanced oil recovery ($CO_2$-EOR) sites, International Journal of Greenhouse Gas Control, Vol. 51, pp. 369-379 (2016).

**Figure 1.17: Emissions in Japan by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 1,295 Mt |
| $CO_2$ emissions | 1,190 Mt |
| Population | 126.8 million |
| GDP (in USD million) | 4,859,950 |
| Per capita emissions | 10.17 t |
| Share of global emissions | 2.70 % |




Japan has a very high share of emissions from electricity generation.

Sources: PIK, EDGAR, World Bank

gas, regarding them as primary energy sources that are sufficiently and competitively available on the global market.

The Japanese Ministry of Economy, Trade, and Industry (METI) also sees great opportunities in renewable hydrogen;[43] hydrogen can also be produced in a climate-friendly manner in combination with CCS, and can contribute to the diversification of primary energy imports. From a technological point of view, Japan is also in an excellent position to drive forward innovations in hydrogen technology. METI sees applications here with respect to power generation, industrial processes, and transport.

For a country like Japan, which is highly dependent on imports and has little renewable energy potential of its own, strategic partnerships with potential hydrogen exporters are also very important. Accordingly, Japan concluded a technology partnership with Australia at the beginning of 2020.[44] As early as the end of 2019, Kawasaki Heavy Industries announced the start of construction of the *Suiso Frontier*, a ship for the transport of liquid hydrogen, which is to sail the route between Australia and Japan from the end of 2020.

**Summary:** Japan plans to achieve climate-neutrality by 2050, using technologies such as CCS in order to maintain the high proportion of coal-fired power plants in the electricity sector. The use of hydrogen in the electricity, transport, and traffic sectors is also being promoted.

## China

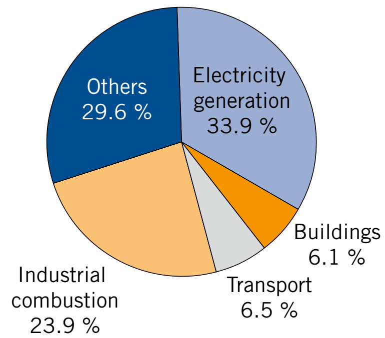
In its submitted NDC, China stated that its $CO_2$ emissions will reach their highest level in 2030 at the latest, and should fall from then on. This decline is to be reached by more stringent targets for energy intensity, but these alone will not lead to a reduction in absolute emissions. At COP25, there were indications that China would like to submit a more ambitious NDC, but this has yet to occur.

China presents a very varied picture, which comes as no surprise for a country of its size. According to a research institute of the state-owned energy company State Grid China, at least 1,250 GW of coal-fired power plants will be needed in China in the long term to guarantee secure supply, which is almost 30 times the installed capacity of

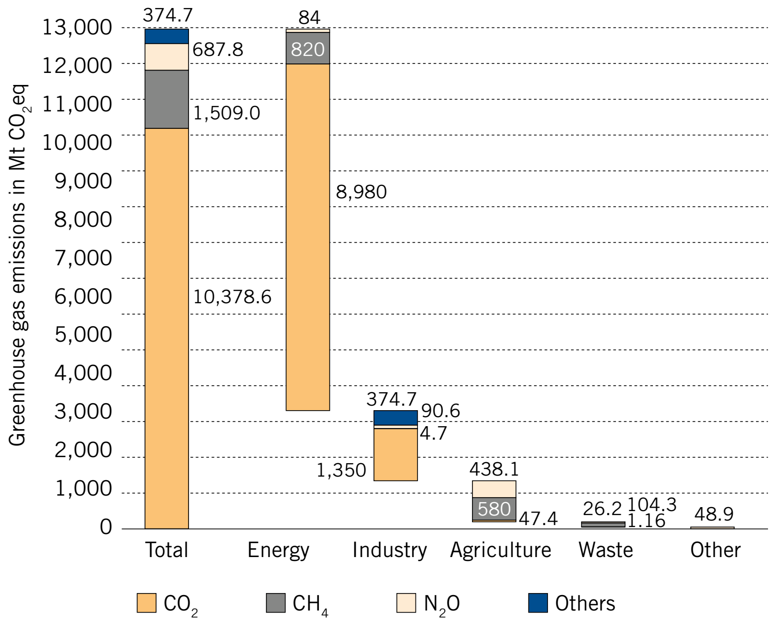
43 METI, Basic Hydrogen Strategy (2017).

44 Media release Department of Industry, Science, Energy and Resources, Australia, Japan agreement an exciting step towards hydrogen future, [https://www.minister.industry.gov.au/ministers/canavan/media-releases/australia-japan-agreement-exciting-step-towards-hydrogen-future] (10 January 2020).

**Figure 1.18: Emissions in China by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 12,950 Mt |
| $CO_2$ emissions | 10,379 Mt |
| Population | 1,386.40 million |
| GDP (in USD million) | 12,143,491 |
| Per capita emissions | 9.38 t |
| Share of global emissions | 27.26 % |




In 2017, China accounted for over a quarter of global GHG emissions, with high shares from electricity generation and industrial combustion. The relatively low per capita emissions compared to other industrialised countries indicate further potential increases.

Sources: PIK, EDGAR, World Bank

coal-fired power plants in Germany.[45] However, there has recently been no lack of indications that the reserve margins of 50 percent in the Chinese system have been more than adequate for some time, and that the required expansion will be quite low.[46] In some cases, coal-fired power plants are operating at less than 50 percent capacity.[47] China's five-year plan for the period 2016-2020 sets a 58 percent limit to coal's share of the energy mix. The latest information confirms the expansion forecasts for coal-fired power plants, with the China Electricity Council expecting coal-fired power plant capacity to reach around 1,250 GW by the end of 2025 (200 GW more than in 2020). In addition, Chinese companies are very active outside of China in coal production and the construction of new coal-fired power plants. At the same time, China is one of the leading producers of renewable power plants and electric cars. China is also planning to introduce a national emissions trading system in 2020 and a mandatory system with renewable certificates and different targets for the provinces.

## China plans for emissions to peak by 2030 at the latest

If China wants to reach the targets in the Paris Agreement, a very steep path of reductions will have to be followed after 2030, which will present China with major challenges. China is aware of this, and has launched a national near-zero carbon pilot program as part of its five-year plan. One example is Meishan, which has developed from a fishing village to a city with a port over the last 20 years. The development plan assumes that the population will grow by a factor of 3.3 by 2030 and the economy by a factor of 3.8. However, total emissions in Meishan should remain below the 2017 level (around 300,000 t $CO_2$), as opposed to quadrupling as per a business-as-usual scenario. The main contribution to achieving this target will be made by the electricity mix (49.8 percent of the reductions), where energy supply will no longer depend on coal, instead relying on a mix of renew-

45 Bundesnetzagentur, power plant list (as at 1 April 2020): 43 GW net installed capacity for lignite and hard coal-fired plants.

46 Jiang Lin et al., A regional analysis of excess capacity in China's power systems, Resources Conservation and Recycling 129, pp. 93-101 (February 2018).

47 Carbon Brief, Analysis: Will China build hundreds of new coal plants in the 2020s? (24 March 2020).

able energies (which will account for 71 percent of primary energy consumption), and gas. Efficiency measures in the industrial, transport, and buildings sectors will also contribute (36.9 percent of the reductions), and the remainder of reductions (13.3 percent) will be achieved through a focus on low-emission industries in the further development of the economy.

Favoured by steeply decreasing costs and state subsidies, the share of renewable energies in the energy mix (especially solar and wind energies) has increased strongly over the last five years. Today, it amounts to almost 20 percent with respect to the installed generation capacity, and approximately 10 percent with respect to the amount of electricity generated. Hydropower comes on top of this, accounting for around one-fifth of electricity generation and power plant capacity. In the past, a strong focus on the expansion of solar and wind power led to temporary generation surpluses which could not be used due to restrictions in the grid. Despite a significant reduction in feed-in tariffs in recent years, the Chinese government is continuing its support for renewable energies with a much stronger focus on grid integration.

Rather than focusing on existing structures, China is concentrating its climate-neutrality measures on regional and urban development in areas that are still being developed. However, it remains to be seen when the pilot projects will be implemented on a larger scale.

China is (or at least was) a pioneer in the transport sector:[48] it accounted for 50 percent of the global market for electric cars in 2018. However, after subsidies were reduced by half, this market collapsed. Nevertheless, experts still expect the target of five million electric cars sold by 2020 to be reached, and the number of electric cars was estimated at 3.8 million at the end of 2019.[49] In parallel, China is setting new targets for hydrogen mobility, with plans for one million fuel cell vehicles by 2030.

**Summary:** China is responsible for around one-quarter of all GHG emissions, so policy relating to climate change measures in the country has a major impact on the entire world. Climate protection measures are being implemented especially at the local level, and will be transferred across the entire country in future. Policy measures include the promotion of renewable energies, electric and hydrogen mobility, as well as the establishment of emissions trading systems.

## India

India is the world's third-largest emitter of GHGs. Like China, the country has relative rather than absolute emission targets up to 2030. To reduce emission intensity, India wants to increase the share of non-fossil fuel power generation to 40 percent by 2030 and achieve cumulative sinks of between 2.5 and 3 Gt $CO_2$ by 2030 through afforestation projects. The strong expansion of renewable energy sources is expected to help achieve this goal; by 2022, 175 GW of renewable capacity is planned to be built, and Prime Minister Modi has set a long-term target of 450 GW, although the timing of this remains open.[50] At the end of 2019, around 32 GW of PV, 37 GW of onshore wind, and 15 GW of small hydro had been installed. Of these technologies, PV, in particular, has demonstrated exceptionally strong growth rates in recent years.

> India aims to strengthen $CO_2$ sinks with forest projects

However, in addition to the significant expansion in renewables, coal is also growing strongly. Among coal producers, India is a close second to China, and coal accounts for around three-quarters of India's electricity production. As such, India faces the difficult balancing act of ensuring the country's further development (many of the UN Social Development Goals are closely linked to electrification), while respecting climate targets at the same time. There is some hope that the current addition of 50 GW of new coal-fired power plants will lead to older coal-fired power plants being taken off the grid.

While India regards CCS as a potential solution, its use is still being reviewed. There are, however, plans for a small CCUS project and an EOR project. In addition, there have only been a few studies on geological storage options in India so far, so there remains a great deal of uncertainty.[51]

With respect to electromobility, India has set itself the target of 30 percent electric vehicle penetration by 2030. Parallel to this, India sees great opportunities for itself in the development of electricity storage systems, and is

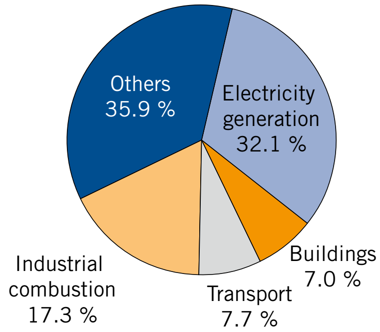
48 Lutz Berners, Chinas NEV-Strategie 2021-2035, OWC Außenwirtschaft (24 March 2020).

49 Simon Göss, China´s 2019 electricity generation reviewed as its next 5-year plan is drafted, energypost.eu (24 March 2020).

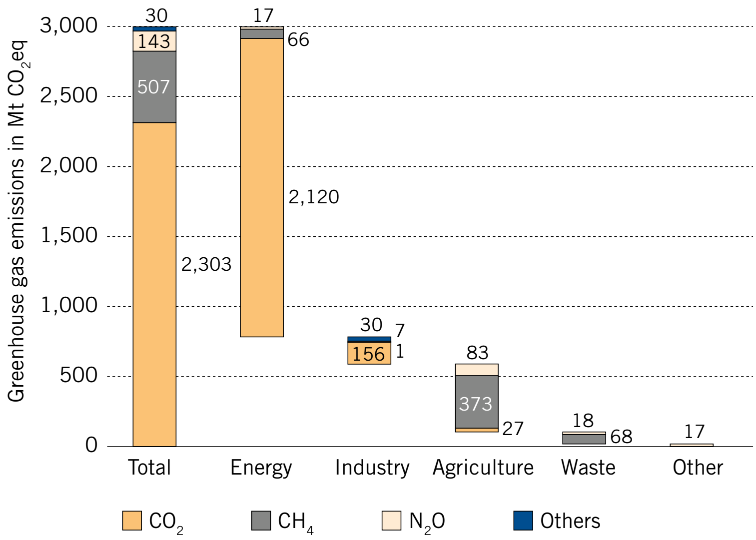
50 IEA, India 2020 – Energy Policy Review (January 2020).

51 Peter Viebahn et al., Future CCS implementation in India: a systemic and long-term analysis, Energy Procedia 4 2708-2715 (2011).

**Figure 1.19: Emissions in India by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 2,983 Mt |
| $CO_2$ emissions | 2,303 Mt |
| Population | 1,338.7 million |
| GDP (in USD million) | 2,652,243 |
| Per capita emissions | 2.23 t |
| Share of global emissions | 6.25 % |




India has a relatively high share of emissions from electricity generation. Despite the size of the country, transport emissions do not (yet) play a major role. Per capita emissions are well below those for industrialised countries, which indicates high potential for increasing emissions.

Sources: PIK, EDGAR, World Bank

supporting this with research funds. In 2017/2018, India spent a total of around USD 110 million on research in the field of clean energy.

**Summary:** India is currently pursuing relative climate protection goals, such as the expansion of renewable energies and afforestation projects. The electrification of the country in pursuit of development stands partly in conflict with climate protection; three-quarters of India's electricity generation is based on coal. In the future, CCS could prove to be an important climate protection option for India. Electromobility and electricity storage technologies have been given high priority.

## Africa

Africa's contribution to global GHG emissions is still small. In all scenarios, the IEA expects this to remain the case until 2040,[52] despite the significant economic and population growth that is expected on the continent. The five largest emitters together account for half of all African emissions: South Africa (18 percent), Nigeria (11 percent), Egypt (10 percent), Algeria (8 percent), and Ethiopia (4 percent).

> **Through a leap in technological development, African countries could become low-GHG industrialised countries**

Technological improvements and the availability of resources open up opportunities for Africa to adopt a low-carbon development model, in which less coal and gas are used to satisfy the growing hunger for energy than in other countries. Africa has enormous potential in terms

52 IEA, Africa Energy Outlook 2019 (November 2019).

of hydropower and solar energy. However, if this potential is not realised, there is considerable risk that Africa will increase its GHG emissions significantly as its industrialisation progresses. This is indicated by the pledges submitted so far: in the best case, they add up to 5.3 Gt per year in 2030 – a significant increase compared to the 3.0 Gt for 2017.

A number of African countries are among the 73 parties to the Climate Ambition Alliance, including Benin, the Democratic Republic of the Congo, Namibia, and South Sudan. In addition, there are a number of local initiatives, such as those in South Africa, which aim for zero-carbon buildings.

Due to its rich forests, Africa also plays an important role as a $CO_2$ sink. In addition, there are also recent indications that soil degradation can be a major source of GHG emissions.[53] As such, significant gains for global climate protection can be achieved in Africa by protecting existing environmental resources. One notable example of this is the Great Green Wall Initiative (GGWI), which reforested a green belt along the Sahara desert in 2007, and aims to restore 100 million hectares of currently degraded land by 2030, which will sequester around 250 Mt $CO_2$.[54]

**Summary:** Low GHG emissions are predicted for the African continent up to as late as 2040. The potential of $CO_2$ sinks, especially through afforestation, can play an important role. Individual countries are establishing climate protection targets and measures, in some cases across borders.

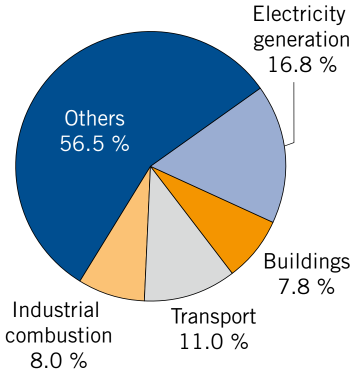
## Chile

Chile is currently formulating a new framework law for climate change. The main objectives of this are to achieve GHG neutrality by 2050, increase resilience to the impacts of climate change, and meet international climate change commitments. The current draft law (as at the beginning of 2020) includes governance and management instruments, financing measures, and economic instruments. A $CO_2$ tax is also to be used as an instrument; thermal power plants larger than 50 MW will be subject to a tax of USD 5/t $CO_2$. Following an amendment

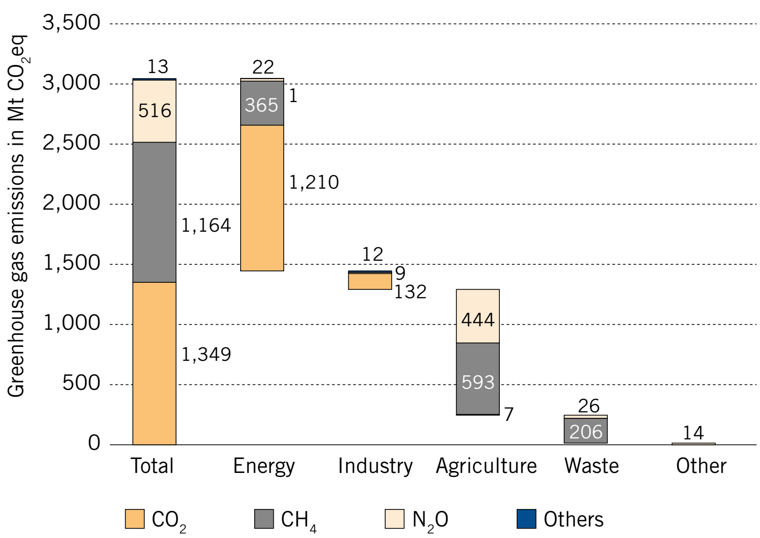
53 University of Edinburgh, Satellite study reveals that area in Africa emits one billion tonnes of carbon, ScienceDaily, [http://www.sciencedaily.com/releases/2019/08/190813112213.html] (13 Aug 2019).

54 [https://www.unccd.int/actions/great-green-wall-initiative].

**Figure 1.20: Emissions in Africa by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 3,042 Mt |
| $CO_2$ emissions | 1,349 Mt |
| Population | 1,245.1 million |
| GDP (in USD million) | 2,280.27 |
| Per capita emissions | 2.44 t |
| Share of global emissions | 6.38 % |




Due to the low level of industrialisation, emissions from agriculture have a large share of total emissions in Africa.

Sources: PIK, EDGAR, World Bank



WORLD ENERGY COUNCIL | WELTENERGIERAT DEUTSCHLAND to the law in spring 2020, the tax will apply to power plants emitting more than 25,000 t $CO_2$ per year.[55]

## Chile has excellent prospects of becoming an exporter of renewable hydrogen

At the beginning of June 2019, the government also presented a detailed timetable for the first phase of the decommissioning of the country's coal-fired power plants, whereby eight power plants are to be shut down by 2024. The plan was implemented a few days later with the decommissioning of two 171 MW units at the Tocopilla power plant after over three decades of operation. In the second phase, the country's remaining 20 coal-fired power plants will be shut down by 2040. The Chilean government has pledged to accelerate regulatory changes and investments to make the announced closures feasible. According to the Chilean Ministry of Energy, Chile currently has projects for 602 kilometres of transmission lines and 3,562 MW of power plants, and some 97 percent of these are renewable energy projects.

Chile also sees opportunities to transform itself from an energy importer to an energy exporter in future. The high quality of its location for renewable energies can make Chile a supplier of renewably produced hydrogen and its derivatives.[56]

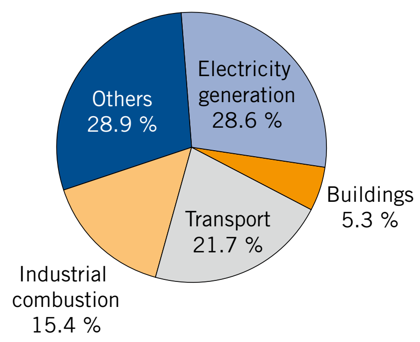
In addition, Chile wants to expand its national sinks through forest projects. At the end of 2019, Chile signed an agreement with the Forest Carbon Partnership Facility (FCPF) to increase the absorption capacity of its forests.

**Summary:** Chile is pursuing its goal of climate neutrality primarily through expanding renewable energies and shutting down coal-fired power plants. The country is also positioning itself as potential producer and exporter of renewable hydrogen.

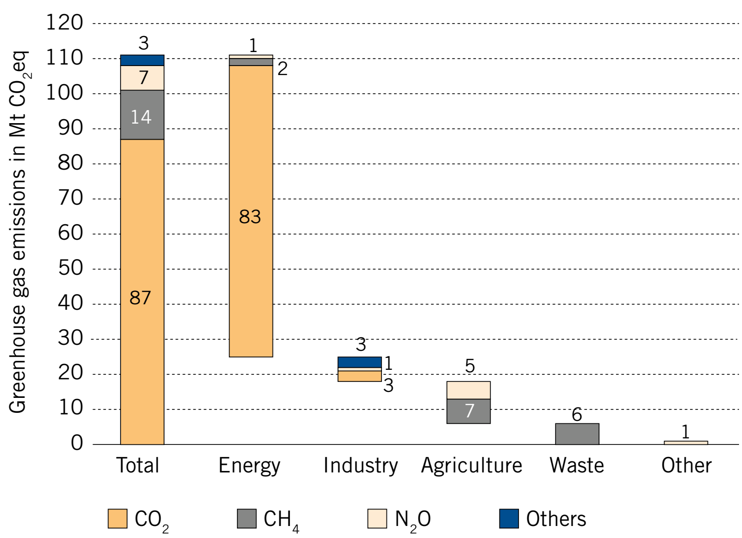
55 International Carbon Action Partnership (ICAP), ETS Detailed Information Chile (last updated 24 March 2020).

56 Frontier Economics, International Aspects of a Power-to-X roadmap (18 October 2018).

**Figure 1.21: Emissions in Chile by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 111.12 Mt |
| $CO_2$ emissions | 86.82 Mt |
| Population | 18.47 million |
| GDP (in USD million) | 277,746 |
| Per capita emissions | 6.01 t |
| Share of global emissions | 0.23 % |




Chile is responding to the relatively high share of emissions from electricity generation with its renewable energy expansion plans, especially as the country has very high potential in this area.

Sources: PIK, EDGAR, World Bank

## New Zealand

In November 2019, New Zealand's legislators passed the Zero Carbon Amendment Act, aimed at reducing GHG emissions to an almost neutral level by 2050, when New Zealand plans to produce no GHG other than methane. Methane is a central component of New Zealand's emissions, as agriculture is one of New Zealand's key exports. Nevertheless, biological methane is to be reduced by 10 percent by 2030, and by 24 to 47 percent by 2050. New Zealand is focusing on national reductions in achieving its targets, and does not plan to use international projects to offset its emissions.

The pathway to an (almost) GHG-neutral New Zealand will be supported by a new, independent Climate Change Commission, which will assist the government in achieving its long-term goals.

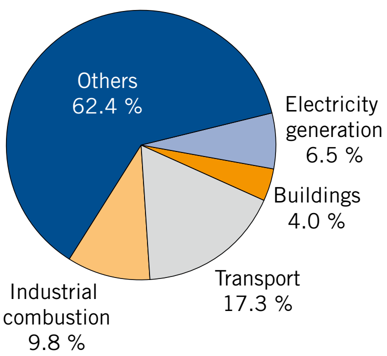
The establishment of emission targets will be a step-by-step process, which will take place through the indicative setting of emissions targets for 2021-2025, followed by targets for 2022-2025, 2026-2030, and 2031-2035, all of which have to be set at least 12 years in advance. As such, the pathway to 2050 is to be determined in an adaptive manner.

### › In New Zealand, methane emissions come mainly from the agricultural sector

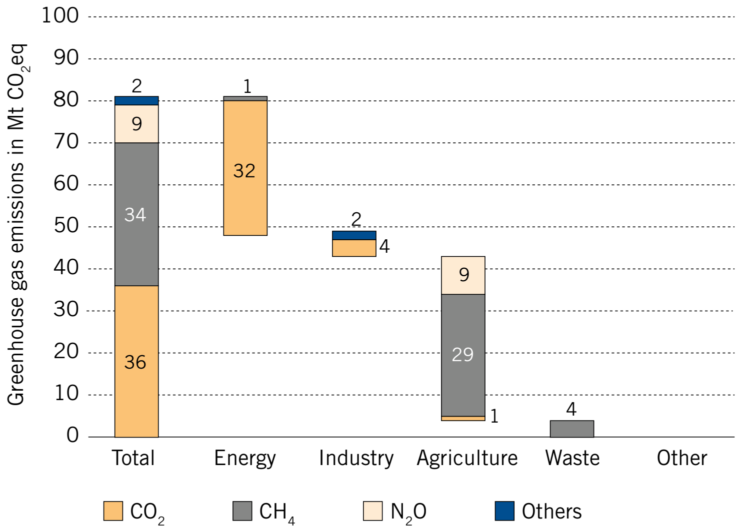
New Zealand generates around 80 percent of its electricity from renewable energies, and these are to be further expanded. More heat pumps are to be used for households, and biomass is to be used for industrial heating. The government is converting its car fleet to electric vehicles, and is working on converting other vehicles to electric vehicles as well. The government has also relaunched a program to subsidise home insulation, and is investing USD 14.5 billion over the next ten years in infrastructure for transport, cycling, and hiking. New Zealand has also committed to planting one billion trees by 2028.

Agriculture is the largest individual source of GHG emissions in New Zealand, accounting for 48 percent of the country's total emissions in 2017. Methane emissions from ruminants accounted for 34 percent of total emissions. Ruminants such as sheep and cattle release methane when digesting grass and other plants. There is no easy way to prevent this, but scientists have found that adding certain plants to animal feed can reduce the amount of methane released.

**Figure 1.22: Emissions in New Zealand by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 81.42 Mt |
| $CO_2$ emissions | 36.46 Mt |
| Population | 4.79 million |
| GDP (in USD million) | 202,590 |
| Per capita emissions | 16.94 t |
| Share of global emissions | 0.17 % |




At just under 50 %, New Zealand has a remarkably high share of emissions from the agricultural sector. Sources: PIK, EDGAR, World Bank

**Summary:** Methane is one of the country's central emissions because of its reliance on the livestock industry. As such, the country will not achieve the target of net zero GHG emissions by 2050. In addition to the expansion of renewables, the government is focusing primarily on electrification and afforestation.

## Bhutan

Over 70 percent of Bhutan is covered by forest, providing carbon sequestration of an estimated 6.3 Mt $CO_2$ p.a.[57] Slash-and-burn agriculture is banned. Overall, Bhutan already has a negative GHG emissions balance.

Electricity generation is largely based on hydropower, and there are expansion plans for further hydropower plants, primarily for export to India. The revenues from these plants play a significant role in the national budget.

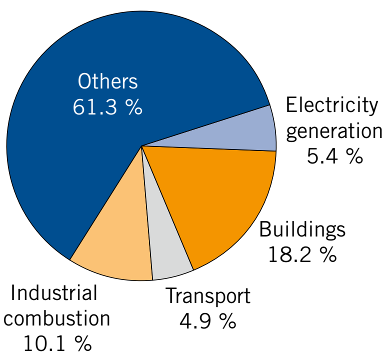
As tourism in Bhutan is limited by a relatively restrictive policy (tourists have to reckon with minimum expenses of USD 200-250 per day for tour guides, accommodation, and food), emissions from tourism are not expected to grow strongly. However, the expected private demand for cars is likely to lead to rising emissions in the transport sector.

### Bhutan has achieved negative total emissions through its forests

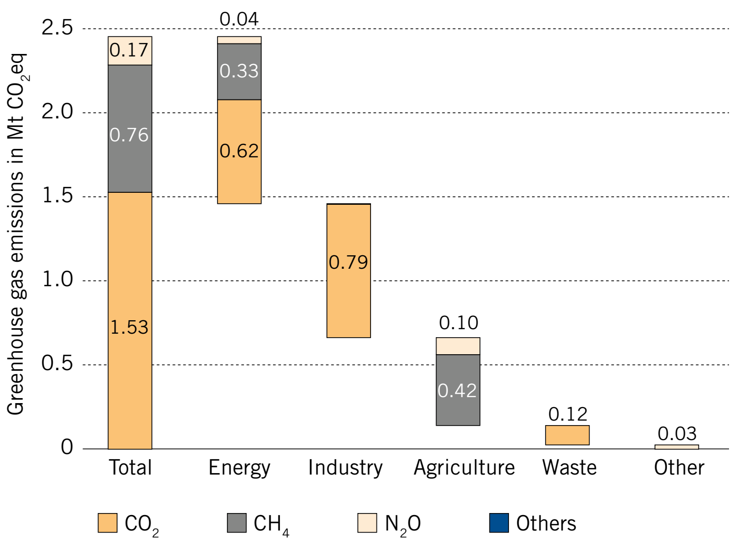
**Summary:** Bhutan is one of the few countries that already has a negative GHG balance, which is in part due to the fact that 70 percent of the country is covered by forest.

57 INDC Bhutan (30 September 2015).

**Figure 1.23: Emissions in Bhutan by source and greenhouse gas (2017)**




| | |
|---|---|
| Total GHG emissions | 2.45 Mt |
| $CO_2$ emissions | 1.53 Mt |
| Population | 0.75 million |
| GDP (in USD million) | 2,534.97 |
| Per capita emissions | 3.29 t |
| Share of global emissions | 0.01 % |




Although Bhutan has higher per capita emissions than India, the high degree of forest cover more than compensates for this, resulting in Bhutan having negative total emissions.

Sources: PIK, EDGAR, World Bank

## Interim summary

In all countries, the bulk of GHG reduction is achieved through reducing GHG emissions through either energy efficiency measures or the expansion of renewable energies. Sector coupling using electricity as an energy source can also help reduce GHG emissions in the transport and heating/cooling sectors, as it provides a substitute for fossil fuels. Energy efficiency ensures a reduction in overall demand for energy – a major cause of $CO_2$ emissions.

A comparison of the different pathways taken by countries in attempting to achieve climate neutrality shows that barely any of them can do without GHG sinks. As in the case of Bhutan, these can be achieved through a very high level of forestation compared to the population and industrial activities. If the natural conditions do not allow this, initiatives can be undertaken which, by means of CCS or CCUS, either store the $CO_2$ or feed in into a cycle. Negative contributions can be achieved if CCS is coupled with biomass, or where the $CO_2$ is stored over a longer period of time in the end products.

Some countries already rely on the import of climate protection services in order to make the costs on the path to a climate-neutral world manageable, or to contribute to the dissemination of technologies.

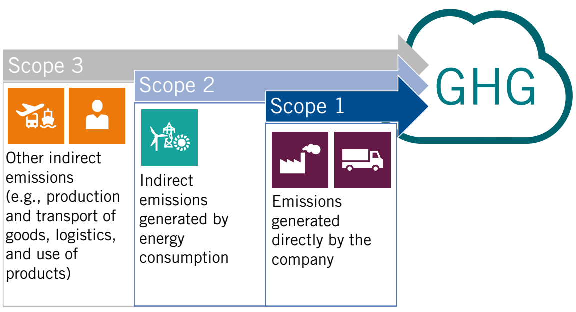
## 1.3 Climate neutrality for companies

Complementary to countries and the laws and regulations they use as measures to achieve climate neutrality, companies, operating in the context of national and international agreements and laws, also play a role. They act on the basis of the incentives and restrictions that set a framework for their economic activities. It is important to note that it is not possible per se to equate or reconcile government emissions targets with climate neutrality targets in companies. Multinational corporations, for example, generate emissions in a number of countries, which makes their attribution difficult.

The interpretation of these very different frameworks is a strategic decision for every company. The achievement of climate neutrality can be considered an essential component of long-term risk management. As GHG emissions have to be reduced in the long term (and it is still open as to what proportion of this will be achieved through emission reduction and what through GHG sinks), companies are preparing for this with their own climate neutrality goals. Along the way, they are learning about the potential for emission reduction in their own activities, and to what extent production processes can be made less GHG intensive through innovation. In pursuing these activities, it also becomes clearer to companies whether there is a basic level of GHG emissions that cannot be reduced (except by discontinuing these activities) or only reduced at very high cost. Consequently, negative emissions are needed in order to meet the requirements of climate neutrality. Companies are already anticipating stricter efficiency standards, fiscal changes, and tighter regulation.

Internationally recognised standards provide the framework and define the accounting for GHG, the manner in which financial reporting is conducted, and the preparation of sustainability reports (e.g., the Greenhouse Gas Protocol, SASB Sustainability Accounting, and the Global Reporting Initiative).

**Figure 1.24: Classification of emissions according to scope 1, 2, and 3**




Source: Siemens

If all companies in a country were to achieve climate neutrality, they would be able to make a relative contribution to the country's climate target, but with limitations. Firstly, significant emissions take place outside of companies (e.g., by private households). Secondly, some voluntary measures taken by companies have a zero-sum effect (i.e., one company is credited with lower GHG emissions, while higher emissions are attributed to other companies or households). For example, companies whose energy consumption is primarily driven by electricity consumption can improve their carbon footprint relatively easily by purchasing green electricity. However, this will increase the "non-green" share of electricity for all other electricity consumers, as the share of available green electricity in the system does not increase in line with demand (unless the electricity purchased is specifically linked to the construction of new plants). This effect does not occur in a cap and trade system, such as the European Union Emissions Trading Scheme, as total emissions are capped here. The associated long-term expectations thus also provide an incentive to develop climate-friendly technologies.

In addition, there are institutions that promote the publication of company data on environmental and climate risks by setting a standardised framework, such as the Carbon Disclosure Project (CDP) or the Task Force on Climate-related Financial Disclosures (TCFD). This allows investors to better assess the risk of their investments in these areas.

The Greenhouse Gas Protocol (GHG Protocol), a widely used international standard for recording a company's own GHG emissions, describes three areas ("scopes") for accounting for GHG emissions:

- scope 1: All direct GHG emissions (i.e., from sources within the organisational boundary of a company);
- scope 2: Indirect GHG emissions from electricity, steam, heating, and cooling generated outside of a company, but purchased by the company; and
- scope 3: All other indirect emissions, including from the extraction, production and transport of purchased materials or goods, the distribution and use of sold products or services, the disposal of waste, as well as emissions from business travel.

Typically, companies have direct influence on scope 1 and scope 2, and can control the associated emissions. This is not the case with scope 3 – especially when the products are used by end consumers. Nevertheless, a stringent consideration of scope 3 emissions can result in companies changing their product range. It should be noted, however, that this type of accounting can involve double counting. For example, an electricity producer may generate scope 1 emissions, which are then also recorded as scope 2 emissions at the consumer level. The boundaries of how far emissions need to be recorded in the downstream chain are also somewhat arbitrary.

The distribution of emissions between the three scopes varies strongly from sector to sector. Companies in the IT sector typically record high scope 2 emissions, making energy procurement from $CO_2$-free power generation a reliable means of reducing emissions. Logistics companies generally have high scope 1 emissions, so can achieve reductions by introducing efficiency measures and then gradually transitioning to climate-neutral fuels.

In principle, three types of company can be differentiated:

- companies that realise emission reductions because of the economic advantages from the use of climate-friendly technologies. For example, by using combined heat and power (CHP) or by switching to a more climate-friendly fuel such as gas;
- companies that are forced to use climate-friendly technologies due to legal regulations and requirements; and
- companies that realise competitive advantages or higher sales prices for their products by using climate-friendly technologies and reducing $CO_2$ emissions.

Voluntary associations of companies that commit themselves to climate targets have seen a strong increase in membership. These initiatives differ in their respective objectives. While the circa 80 companies participating in EP100 have set themselves the goal of doubling energy efficiency within 25 years, the over 200 participants in RE100 are pursuing the goal of obtaining their electricity entirely from renewable sources by 2050. In the meantime, the targets of more than 300 companies have also been validated as part of the Science Based Targets initiative (SBTi). In line with the latest scientific findings and as set out in the Paris Agreement, these targets aim to limit global warning to well below 2 °C. The GHG emission targets are mandatory, and are set according to the SBTi criteria for the various scopes. According to Bloomberg, by 2030, the emission reduction of companies with validated SBTi targets will be approximately 200 Mt $CO_2$eq per year (approximately equivalent to the annual emissions of the Netherlands). Currently, around 500 additional companies are in the process of committing to the SBTi and setting targets.

The starting point for the individual companies varies greatly. Due to the nature of their value creation, energy-intensive companies like electricity producers, transport and logistics companies, and steel producers have to reduce very large amounts of emissions to achieve climate targets (often set by themselves). In contrast, these targets are usually much more cost-efficient to achieve for companies that generate their turnover from services, such as banks, insurance companies, and trading companies. The mechanisms available to companies today for reducing emissions vary in complexity:

## Reduction through changing the business model

At present, many particularly energy-intensive processes have no economic substitute that is sustainable. In these cases, companies have to assess the risk and future business prospects, and decide based on these whether a change in the business model is necessary.

Ørsted is a frequently cited example of radical business transformation. The energy company has set itself very ambitious goals. The energy intensity of energy production is to be reduced by 96 percent by 2023 (from 2006 levels). This will be achieved by selling the company's oil and gas business, phasing out coal by 2023, converting the coal and gas power plants to biogas, and strongly expanding offshore wind power generation. Since 2006, the company has been able to reduce its greenhouse gas intensity by 67 percent, cut coal-fired power generation by 82 percent, and contribute to a significant reduction in the cost of offshore wind power generation.[58]

58 Science Based Targets initiative, Science Based Targets Case Study: Ørsted, [https://sciencebasedtargets.org/wp-content/uploads/2018/03/SBT_Orsted_CaseStudy.pdf].

### Reduction through changing the generation structure

Another way to protect the climate is to change the method of electricity generation. RWE, for example, aims to become climate-neutral by 2040. Between 2012 and 2019, the group reduced its annual $CO_2$ emissions by 51 percent, and plans a 75 percent reduction by 2030. The gradual phase out of coal-fired power generation plays a central role in this. By 2040, the RWE group's electricity production is to be converted to such an extent that the company can claim climate-neutrality. This will involve a rapid expansion of renewable energies (especially wind power and photovoltaics), the increased use of storage technologies, and the use of $CO_2$-neutral fuels for power generation.[59]

### Reduction through increased efficiency

An increase in energy efficiency in the areas of process energy, transport energy, heating, and electricity offers not only a significant reduction in the carbon footprint, but also the realisation of considerable savings. For example, hotels can achieve high savings by introducing energy management systems and efficient buildings. The Hilton Hotel chain was able to reduce energy intensity by 20 percent and carbon dioxide emissions by 30 percent in the period from 2000 to 2018. The resulting savings for electricity, water, and heating totalled more than USD 1 billion.[60]

### Reduction through purchasing from sustainable energy sources

Another option is the substitution of fossil energy sources (or products from fossil energy sources) by sustainable energy sources or products. This can be achieved through various instruments: the purchase of certificates, on-site power generation, power purchase agreements (PPAs), and investment in sustainable projects. A large market has emerged for these in recent years – especially for PPAs. In 2019, companies concluded contracts for over 19 GW of generation capacity worldwide, an increase of 40 percent from 2018. The largest buyers of renewable energy (mostly solar and wind power) were large technology companies in the United States. Google, Facebook, Amazon, and Microsoft secured an accumulated generation capacity of over 5.5 GW.[61]

### Reduction through the decarbonisation of suppliers

In addition to measures that companies take with regard to their own processes to increase energy efficiency and reduce emissions, many companies set standards for their suppliers to reduce energy consumption and emissions throughout the product lifecycle. Typical examples include Apple and Volkswagen, which carry out sustainability audits and reviews on suppliers to monitor compliance with environmental standards.[62]

Microsoft goes one step further than this. From 2030 on, the company wants to achieve negative emissions and, through these, reverse its historical $CO_2$ emissions by 2050 through applying negative emissions technologies such as afforestation, reforestation, soil carbon sequestration, BECCS, and DACCS.[63]

59 RWE Aktiengesellschaft, Annual Report 2019, Essen, [www.rwe.com/ir (March 2020).

60 EP100, EP100 MEMBERS, [https://www.theclimategroup.org/EP100-members].

61 Bloomberg New Energy Finance (February 2020).

62 More information available at [https://www.apple.com/de/supplier-responsibility/] and [https://www.volkswagenag.com/de/news/2019/06/volkswagen-group-commits-suppliers-to-sustainability.html].

63 Brad Smith, Microsoft will be carbon negative by 2030, Microsoft, [https://blogs.microsoft.com/blog/2020/01/16/microsoft-will-be-carbon-negative-by-2030/] (16 January 2020).

## 1.4 Measures to reduce greenhouse gas emissions

To reach the 2 °C target, a wide range of different options can be considered, with measures relating to both consumption and production.

### Negative emissions technologies can remove GHG emissions from the atmosphere

On the consumption side, two measures can be distinguished: increases in energy efficiency and changes in behaviour. These can lead to a reduction in demand for energy-intensive goods and services, or to changes in value chains. One example of this is the purchase of local products, which may have lower associated energy consumption due to the shorter transport distances.

In energy supply, a distinction can be made between switching to fuels with lower relative GHG emissions, increasing generation efficiency, and switching to zero-emission technologies such as wind and solar.

Negative emissions present an opportunity to remove GHG emissions from the atmosphere and thus offset emissions generated in other places.

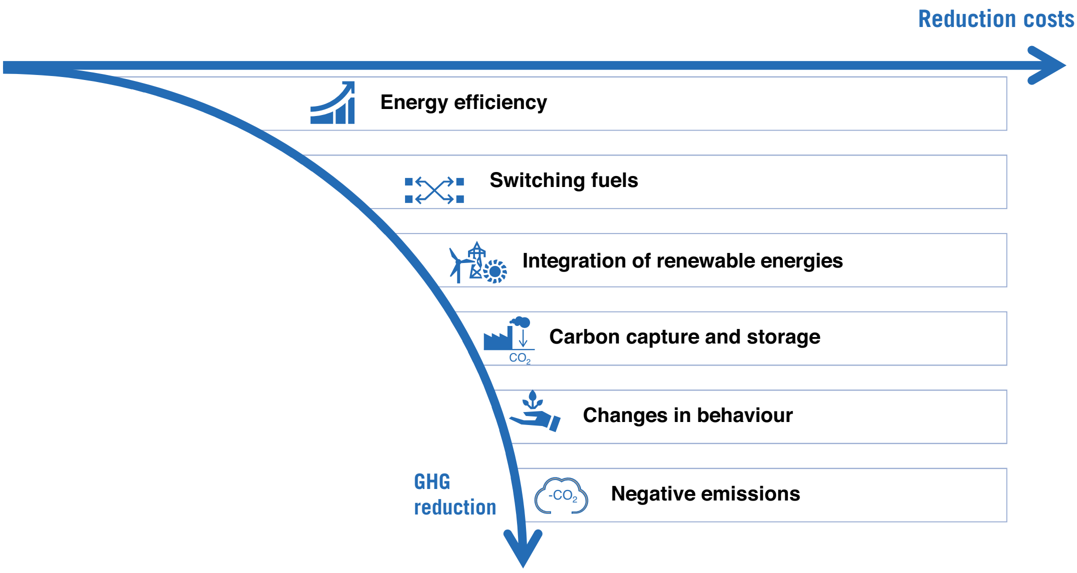
### In 2018 global energy efficiency improved by only 1.2 %

Previous international efficiency gains have been well below expectations. In 2018, for example, energy efficiency improved by only 1.2 percent – 1.8 percentage points below the average 3 percent improvement consistent with the IEA's Efficient World Strategy. One of the causes of this is an increase in the comparatively inefficient generation of electricity from fossil fuels. Coal-fired power generation, for example, rose by 3 percent in 2017 and 2.5 percent in 2018, despite declining use in previous years. The driving forces on the consumption side include shifts in economic output towards industries with high energy requirements, particularly in the United States and China.[64]

Changes in behaviour are influenced by a wide variety of factors. In developing countries, for example, rising standards of living contribute to changes in consumer behaviour, which result in increasing demand for energy to power mobility, air conditioning, and household appliances. The IEA predicts that global demand for air conditioning will triple by 2050, with demand in developing

64 IEA, Energy Efficiency 2019 (November 2019).

**Figure 1.25: Options for reducing greenhouse gas emissions**




Source: Siemens

countries rising particularly sharply.[65] However, new technological developments also hold the promise of reducing energy consumption. Integrated digitally networked mobility concepts create opportunities to combine the strengths of private transport with those of public transport.

Technological development makes it possible to substitute fossil-generated energy with renewable energies. In addition to centralised solutions, such as large wind farms or PV systems, new potential is emerging directly with the end consumer. Consumers are developing into prosumers – individuals who both produce and consume energy. In addition to roof-top PV systems, decentralised combined heat and power plants are also contributing to this trend. Solar thermal systems and heat pumps also allow $CO_2$-free heat generation, thus contributing to the decarbonisation of households. Heat pumps are the most frequently chosen solution for new buildings in Germany – in 2014, 30 percent of new buildings in Germany had them, and a full 44 percent in 2018.[66]

Switching fuels in the electricity sector is another way to reduce emissions. Significantly less emissions are produced when burning oil-based fuels (75 g $CO_2/MJ_{th}$) or natural gas (50 g $CO_2/MJ_{th}$) than coal (100 g $CO_2/MJ_{th}$). Additional potential for reduction can also be realised through higher efficiencies achieved with different combustion technologies and CC(U)S.

Fossil fuels have alternatives in other sectors as well. Vehicles that run on electricity, hydrogen, or synfuels instead of fossil fuels can contribute to significant reductions, depending on upstream emissions. The same applies to heat pumps, which can replace conventional heat generation systems for detached and semi-detached houses, and are also suitable for large-scale application.

This article will analyse the following three topics in more detail:

- going beyond the integration of renewable energies into the electricity system, sector coupling represents a promising and holistic method of reducing emissions;
- the production of substitutes for fossil products from hydrogen will be examined more closely as a key technology. In addition to the use of carbon-neutral sources, the recycling of industrial and power plant exhaust gasses and their use for synfuels offer potential for emission reduction; and
- as the above approaches are usually insufficient to realise the climate pathways calculated by the IPCC, negative emissions technologies to remove $CO_2$ from the atmosphere are finally considered.

65 IEA, The Future of Cooling, [https://www.iea.org/reports/the-future-of-cooling] (May 2018).

66 Bundesverband Wärmepumpen e.V., [https://www.waermepumpe.de/presse/zahlen-daten/].

## Electrification: integration of renewable energies beyond the electricity sector

After reaching a new high in in 2018, the IEA reported a stagnation in global energy-related $CO_2$ emissions in 2019, despite global economic growth of 2.9 percent. This success was mainly due to decreasing emissions in electricity generation, a higher share of renewable energy sources, and a switch from coal to gas and nuclear power. The electricity sector accounts for around 40 percent of emissions, while other sectors such as industry, transport, and buildings account for around 60 percent. While renewable energies accounted for approximately a quarter of the electricity generated in 2018, their share of the other sectors remained significantly lower at approximately 14 percent.

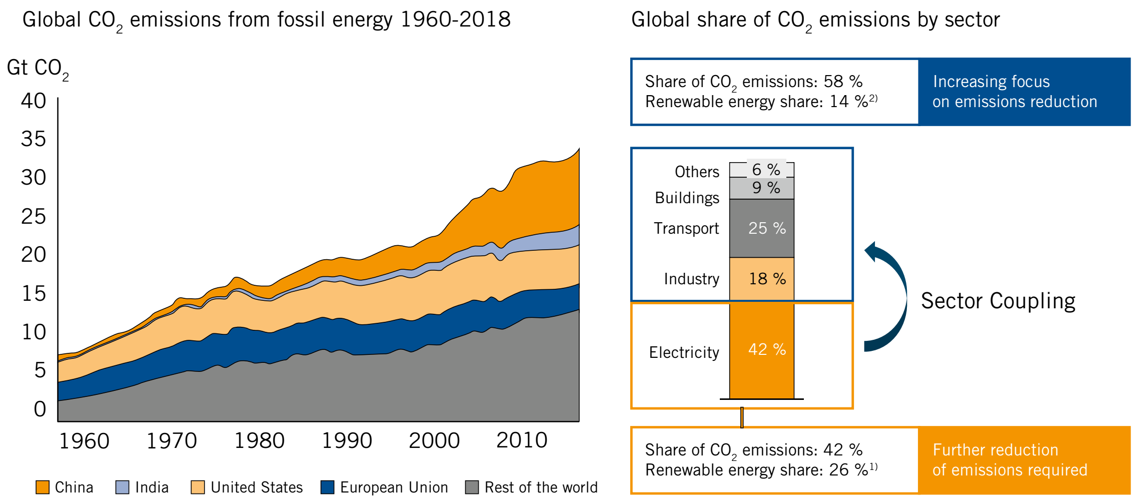
› Renewables account for 26 % of electricity generation

Through electrification, renewable energy can be transferred from the electricity sector to other sectors, thus promoting the decarbonisation of those sectors.

› Renewables account for 14 % of energy in non-electricity sectors

It is generally held that electrification with renewable energy is a prerequisite for achieving decarbonisation rates of over 80 percent. The advantages include higher resource efficiency and better integration of variable renewable energies, and often greater diversification of energy supply and increased import independence. Typical elements of sector coupling are, for example, electromobility, the generation of heat by heat pumps, and the coupled

## Figure 1.26: Global emissions by country and sector

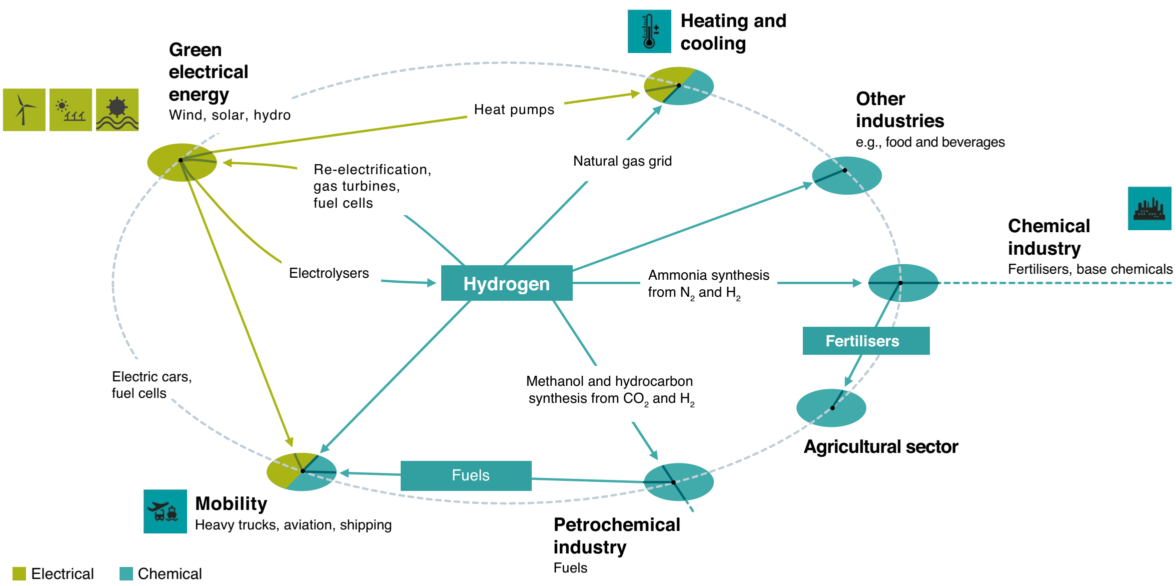



The sectoral breakdown of global $CO_2$ emissions illustrates the important role of sector coupling in the decarbonisation of sectors beyond the electricity sector.

1) Based on electricity production in TWh from non-fossil/nuclear sources.
2) Based on share of primary energy supply.

Sources: Carbon Brief, IEA World Energy Outlook 2019

## Figure 1.27: Potential applications of green hydrogen




Hydrogen opens up new opportunities for the decarbonisation of other sectors and applications.

Source: Power-to-X: Der Schlüssel zu einer $CO_2$-freien Welt, Siemens, 2019 generation of electricity and heat by means of cogeneration for industry and district heating applications. Furthermore, the use of hydrogen opens up additional potential for decarbonising sectors beyond e-mobility and heating/cooling.

### Hydrogen: the key to decarbonising energy, industry, and mobility[67]

Using wind, sun, or other renewable resources, green hydrogen can be produced by means of electrolysis. This can be used directly in the form of hydrogen or can be further processed into synfuels. The hydrogen can also be used as a raw material for chemical products.

> Renewable hydrogen has the potential to replace fossil products in transport, industry, and electricity generation

There are three common electrolysis technologies: alkaline water electrolysis, polymer electrolyte membrane (PEM) electrolysis, and solid oxide electrolyser cell (SOEC) electrolysis. Potential applications of the hydrogen include conversion back into electricity using gas turbines, motors, or fuels cells in times of low renewable generation, or use as a capacity reserve in energy systems with a high share of renewable energy. Other applications include use in industrial processes with particularly high temperature requirements, such as steel production, as well as for combined heat and power applications. The most obvious use, however, is in the transport sector. For example, renewable hydrogen can contribute around 10 percent to the decarbonisation of conventional fuels through its use in the refinery process. Hydrogen also enables emission-free mobility by expanding the hydrogen infrastructure and its use in fuel cell vehicles.

Alternatively, hydrogen can be converted into synfuels. This process uses hydrogen and carbon (for example, in $CO_2$ form) to synthesise fuels. Common products include synthetic natural gas ($CH_4$, obtained using the Sabatier process), methanol ($CH_3OH$), dimethyl ether ($CH_3OCH_3$), aviation fuel, diesel, and hydrocarbon wax (obtained using the Fischer-Tropsch process). These fuels will serve to de-fossilise the transport sector in particular, as it requires very high energy density levels.

Separating nitrogen from the air using air separation plants also enables the production of ammonia ($NH_3$) by means of the Haber-Bosch process. The decarbonised ammonia can be used as a raw material for fertilisers such as urea or ammonium salt. Currently, the process of splitting ammonia into nitrogen and hydrogen is being developed, which would enable the transport of hydrogen in the form of ammonia.

### Reuse of emissions as a substitute for fossil fuels – an area of unrealised potential

In addition to the production of green hydrogen by means of electrolysis using renewable electricity, hydrogen can also be produced from conventional energy sources such as gas (natural gas steam reforming) or coal (coal gasification). Hydrogen produced in this manner is known as grey hydrogen. If the emissions from these processes are captured, stored, and reused by means of carbon capture, the hydrogen is then called blue hydrogen. If hydrogen is produced by electrolysis from electricity generated by fossil fuel power plants whose emissions are captured or stored, it is still called blue hydrogen. Another possibility is decomposing natural gas into hydrogen and solid carbon by means of pyrolysis. The advantage is that the solid carbon can be stored and reused more easily than $CO_2$. Hydrogen obtained in this manner is known as turquoise hydrogen.

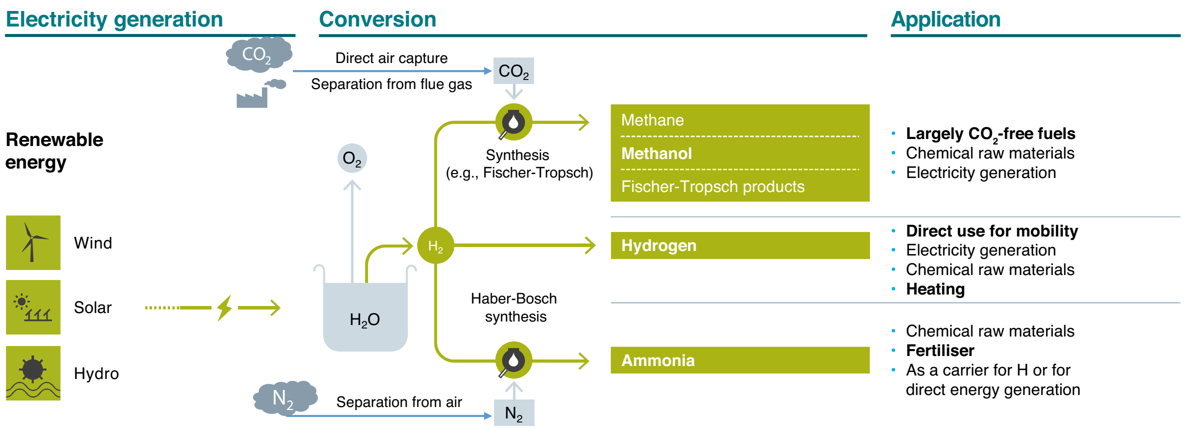
Figure 1.29 provides an overview of various production processes for hydrogen.

> Recycling of $CO_2$ for methanol has been successfully demonstrated – $CO_2$ reduction is also possible for fossil fuels

Synfuels consist of hydrocarbon chains, alcohols, and ethers, and the carbon in these fuels can have a number of sources. It can be obtained from fossil sources as well as from regenerative and thus net $CO_2$-free sources (e.g., biomass combustion plants). A third option is the use of emissions that are by-products of other processes, such as fossil-fuel power generation and industrial processes.

67 Siemens, Power-to-X: The crucial business on the way to a carbon-free world, Technical Paper (2019).

## Figure 1.28: Areas of application for Power-to-X




Three general Power-to-X paths can be distinguished: hydrogen, methanol/hydrocarbons, and ammonia from renewable electricity.

Source: Power-to-X: Der Schlüssel zu einer $CO_2$-freien Welt, Siemens, 2019

One example of this is the $CO_2$ to methanol plant that was completed in 2019 at the Niederaußem coal-fired power plant. Here, up to 1.5 t $CO_2$/day was reused to produce one ton of methanol per day.[68] The electricity for the electrolysis is generated from the surplus electricity from renewable energies. After the successful demonstration of the technology, the synthesis plant was transported to a steelworks in Sweden to recycle $CO_2$ from steel production for use in methanol production. This methanol is used by a ferry company to power a ship.[69]

With the process known as Carbon2Chem, Thyssen-Krupp uses gases from steel production to manufacture chemicals. The process is currently being tested under operating conditions in a pilot plant, and industrial-scale use is planned within the next five to seven years.[70]

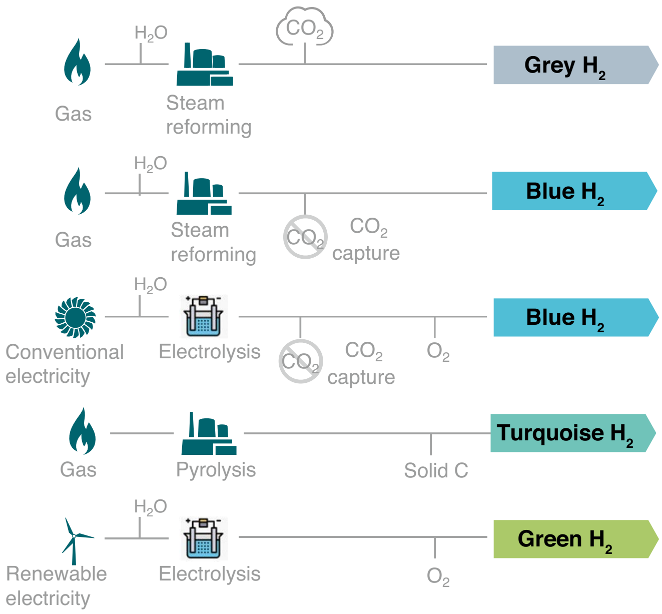
Even when fossil sources are used, emissions can be reduced by substitute fossil fuels. Figure 1.30 provides a theoretical example illustrating the possible influence of reusing emissions. Assuming that 80 percent of the industrial emissions in Germany can be used to produce synthetic fuels (via renewable energies) for reuse in transport, total emissions could be reduced by around 20 percent. A complete reduction of emissions from transport and industry could be achieved by technologies that use renewable energies to capture $CO_2$ from the air.

68 The Mef$CO_2$ project, [http://www.mefco2.eu/project_progress.php].

69 From residual steel gases to methanol, [www.fresme.eu].

70 ThyssenKrupp, Carbon2Chem, [https://www.thyssenkrupp.com/carbon2chem/de/carbon2chem/].

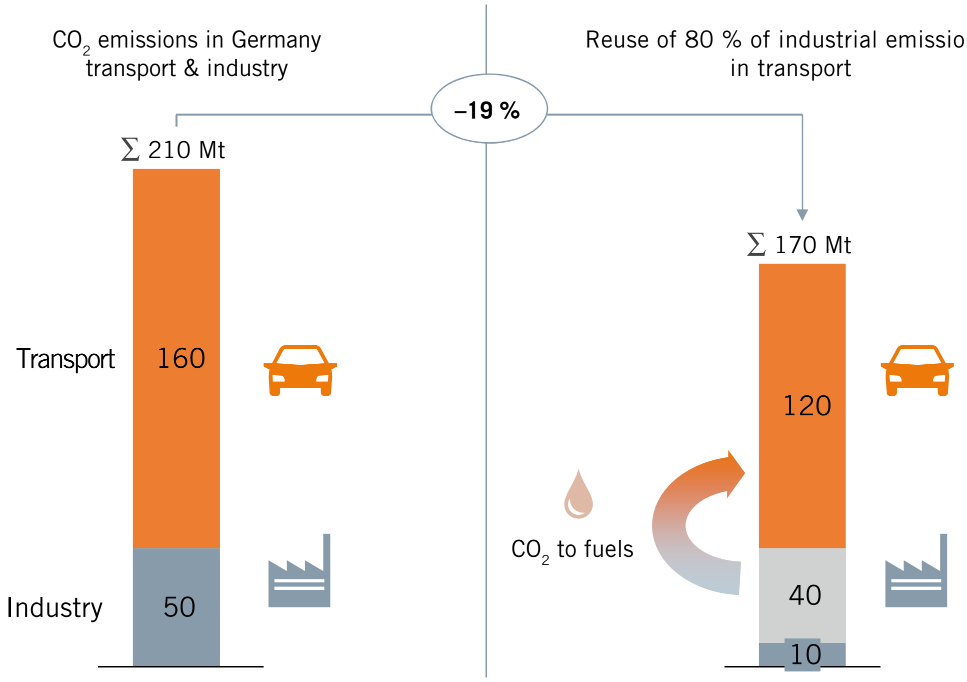
### Figure 1.29: Production techniques for hydrogen




In addition to green hydrogen, there is also grey hydrogen (produced from fossil fuels). and blue hydrogen (produced through the use of carbon capture).

Source: Siemens

### Figure 1.30: $CO_2$ emissions from transport and industry in Germany (2018)




Example of the reuse of emissions through CCUS, using synfuels (generated by renewable energy) in transport.

Source: German Environment Agency data

## 1.5 Negative emissions technologies[71]

Human activities are regarded as the cause of a temperature increase of around 1 °C to date. At the current rate of warming, taking into account the corresponding countermeasures, warming could be kept at 1.5 °C between 2030 and 2050. Different pathways are available to achieve these climate targets. The IPCC is researching various scenarios that are consistent with this 1.5 °C target. Most of these pathways target a 45 percent reduction in anthropogenic emissions by 2030 (from 2010 levels), and achieve net zero emissions by around 2050. Although $CO_2$ emissions have to be balanced by 2050, the IPCC specifies 2067 as the year for net zero for all GHGs in the 1.5 °C scenarios.[72]

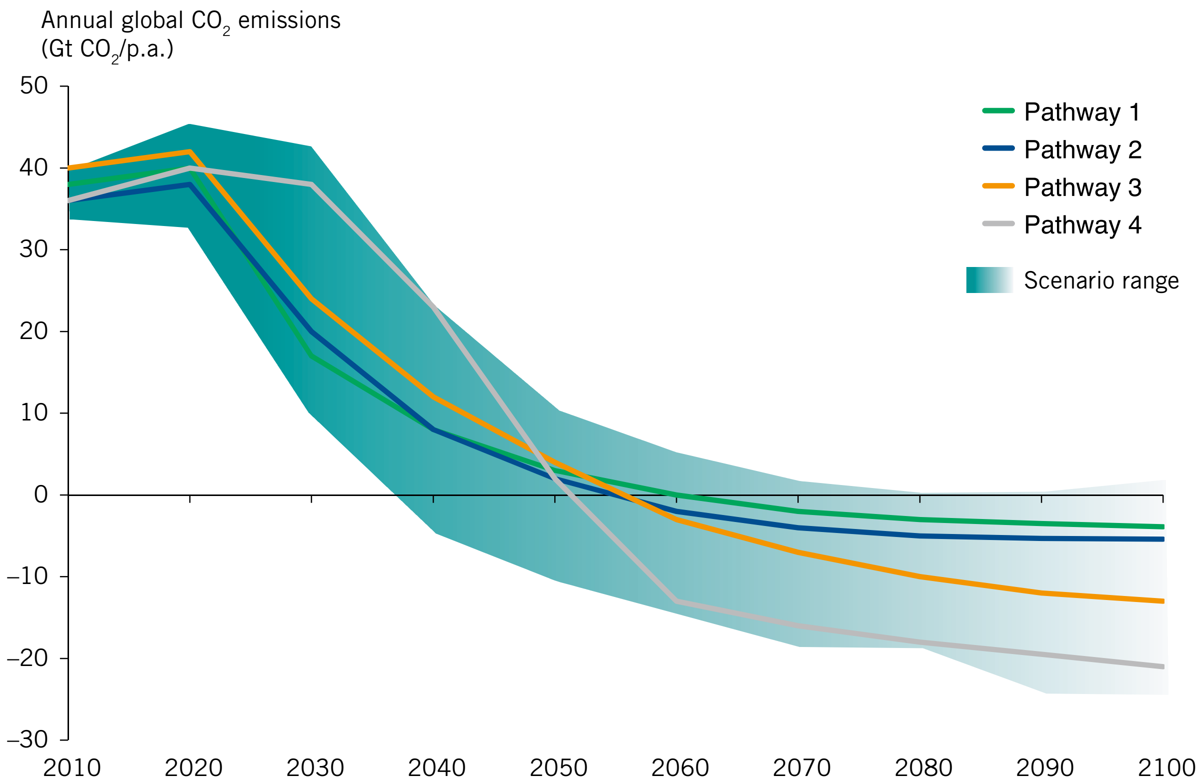
71 IPCC, Special Report on Global Warming of 1.5 °C (2018).

72 Oliver Geden, Felix Genuit, Klimaneutralität als Langfrist-Strategie, SWP-Aktuell No. 38 (July 2019).

> A later reduction in emissions will lead to higher demand for NETs in the second half of the century

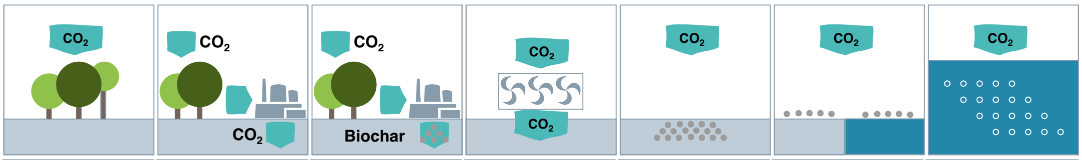
The scenarios describe a variety of options to achieve this goal. As emissions are capped at the aggregate level (rather than being capped at the sectoral level), measures in one sector have an impact on the efforts required in other sectors. The results for the 1.5 °C and 2.0 °C scenarios require almost total decarbonisation in the electricity sector. Stronger emissions reductions in the 1.5 °C scenarios need to be achieved primarily in the transport and industrial sectors. In many of the scenarios, negative emissions technologies are required in addition to CCS in order to achieve the targets. An overview of the range of scenarios consistent with the 1.5 °C target and several selected pathways are illustrated in Figure 1.31.

**Figure 1.31: Emission pathways to a climate-neutral world**




Sources: IPCC Special Report on Global Warming of 1.5°C, 2018, World Energy Council

## Figure 1.32: Potential and costs of GHG sinks




| Negative emissions technology | Afforestation and reforestation | Biomass-energy with carbon capture and storage | Biochar | Direct air carbon capture and storage | Soil carbon sequestration | Enhanced weathering & ocean alkalinity 1) | Ocean fertilisation 1) |
|---|---|---|---|---|---|---|---|
| 2050 potential | 0.5-3.6 Gt $CO_2$/p.a. | 0.5-5 Gt $CO_2$/p.a. | 0.3-2 Gt $CO_2$/p.a. | - | 2.3-5.3 Gt $CO_2$/p.a. | 1-16 Gt $CO_2$/p.a.<br>0.1-10 Gt $CO_2$/p.a. | 0-44 Gt $CO_2$/p.a. |
| Costs | USD 5-50/t $CO_2$ | <USD 200/t $CO_2$ | USD 30-120/t $CO_2$ | USD 100-300/t $CO_2$ | USD -45-100/t $CO_2$ | USD 15-40/t $CO_2$<br>USD 14-500+/t $CO_2$ | USD 2-457/t $CO_2$ |
| Features | • High land and water usage<br>• Lower period of storage than geological storage<br>• Saturation of forests over decades/ centuries<br>• Storage threatened by fire, drought, and pests | • Limited by availability of sustainable biomass and secure $CO_2$ storage<br>• High nutrient and energy consumption<br>• Uncertainties regarding scalability<br>• Land use conflicts | • High land use<br>• Limited maximum storage period determined by available soils<br>• Positive effects on soil fertility | • Costs currently high<br>• Technological challenges<br>• Low land use | • Soil saturation after 10-100 years<br>• Increases soil fertility | • Problematic scalability and side effects<br>• Higher pH values, release of heavy metals, changes to ecosystems | • Major side effects on existing ecosystems |

1) As these technologies are at a very early stage of development, the potential and costs can only be broadly estimated

Source: IPCC Report Global Warming of 1.5°C

Based on the four selected pathways, it is evident that a later reduction in emissions will lead to higher demand for NETs in the second half of the 21st century.

The IPCC delineates two fields of carbon dioxide removal (CDR): technological options and agriculture, forestry, and other land use (AFOLU).

### Afforestation and reforestation

> Afforestation and reforestation are just a couple of the many options to generate negative emissions

Afforestation refers to the planting of trees on land that has been unwooded for a long period of time, while reforestation describes the restoration of original forest areas that have been degraded by human activities. The potential reduction in $CO_2$ is estimated at 0.5-3.6 Gt $CO_2$ per year at relatively low cost (USD 5-50/t $CO_2$eq). Although realising this potential requires high water and land use, the additional energy and nutrient requirements are low. Biogenic storage, limited by the lifespan of the plants, is not as long-term as geological storage. It is also susceptible to external factors such as droughts, pest infestation, and forest fires.

### Biomass-energy with carbon capture and storage (BECCS)

Another method of generating negative emissions is the cultivation of biomass for subsequent power generation, capture and storage of $CO_2$ emissions. Studies estimate the reduction potential of this technology to be around 0.5-5 Gt $CO_2$ per year. This potential is, however, limited by the availability of sustainable biomass and long-term, secure $CO_2$ storage. Negative impacts of the technology include high consumption of land, nutrients, and energy. Moreover, given current investment priorities, it is uncertain whether the technology can be scaled to generate the required quantities of negative emissions without additional policy support.

### Biochar

Biochar is produced from the pyrolysis of biomass. When applied to soils, it increases carbon sequestration while simultaneously boosting soil fertility. Taking into account the availability of biomass, its current potential is around 0.3-2 Gt $CO_2$ per year. The character of the soil and the method of production influence the duration of long-term storage, which can be from a few decades to several centuries. The costs of producing negative emissions are around USD 30-120/t $CO_2$.

## Direct air carbon dioxide capture and storage (DACCS)

The practice of separating $CO_2$ from the air via chemical processes and then storing it is known as direct air carbon dioxide capture and storage (DACCS). An advantage of this technology is that, unlike BECCS, DACCS requires little land use. As with BECCS, however, its potential is limited by the availability of suitable long-term $CO_2$ storage options. The greatest challenge for the technology is capturing $CO_2$ directly from the ambient air, as the concentration of $CO_2$ in the ambient air is around 100-300 times lower than in flue gases from gas- or coal-fired power plants. In addition, the economic viability of DACCS is not yet guaranteed. Studies estimate the costs of negative emissions generated in this way in the range of USD 100-300/t $CO_2$. As the technology is at a very early stage of development, there are no thorough estimates of its overall potential. However, if its costs are significantly reduced, the technology shows promise due to its lack of negative impacts.

## Soil carbon sequestration

Soil carbon sequestration has positive effects on agriculture, such as increased soil productivity and resilience, and is therefore a very cost-effective solution for generating negative emissions. Carbon sequestration can be increased through stronger biomass growth, promoting/facilitating carbonation processes, reducing erosion, facilitating soil formation, developing organic-matter-rich topsoil, restoring degraded or contaminated soils, and through targeted waste management.[73] Studies report costs of USD -45-100/t $CO_2$, and the IPCC estimates the $CO_2$ reduction potential at 2.3-5.3 Gt $CO_2$ per year. Water and energy requirements are low, and no changes to current land use are needed. However, soil carbon sequestration reaches saturation levels after 10-100 years, depending on the chosen sequestration method, soil properties, and climate zone.

## Enhanced weathering and increasing the alkalinity of oceans

Terrestrial weathering is a natural process, whereby rock is broken down in chemical and physical processes and $CO_2$ is consumed and converted into alkaline (bi)carbonates dissolved in the soil. Negative emissions can be achieved through terrestrial enhanced weathering, whereby crushed silicate minerals are spread on land surfaces to accelerate the natural processes. The resulting negative emission potential for this is estimated at 1-6 Gt $CO_2$ per year at a cost of USD 15-40/t $CO_2$. Alternatively, the alkalinity of oceans can be increased by reacting calcium carbonate with $CO_2$, or by producing strong bases and spreading them on the surface of the oceans, thus increasing the $CO_2$ storage capacity.[74] Increasing the alkalinity of the oceans could realise potential of 0.1-10 Gt $CO_2$ per year at a cost of USD 14-500+/t $CO_2$. Negative impacts of these technologies include higher ocean pH values, the release of heavy metals, and changes to ecosystems.

## Ocean fertilisation

The fertilisation of oceans results in increased $CO_2$ storage in coastal waters and subsequent carbon sequestration in the deep sea or in sedimentary deposits. There has been barely any research into this field of negative emission generation. As such, the IPCC has provided only very approximate estimates of its potential (0-44 Gt $CO_2$ per year) and costs (USD 2-457/t $CO_2$). In addition, this technique is considered to have major potential negative impacts on ecosystems.

## Reference projects for the application of negative emissions technologies

### Compensaid[75]

Airlines and other private companies can offer customers the option of offsetting $CO_2$ emissions caused by flights, car journeys, or their private lifestyle. One example of this is Lufthansa's Compensaid program, which allows passengers to offset the $CO_2$ emissions of their flights. Customers are offered the option of offsetting immediately through purchasing Sustainable Aviation Fuel (SAF), which Lufthansa has committed to using on Lufthansa flights within six months of purchase. Alternatively, customers can offset over 20 years through the myforest reforestation project in Nicaragua, or some combination of

73 Humboldt University of Berlin, Kohlenstoffbindung in Böden, [https://www.bodenkunde-projekte.hu-berlin.de/carlos/A01sequestration.html].

74 Max Planck Institute for Meteorology, Ocean biogeochemistry in the framework of "climate engineering", [https://www.mpimet.mpg.de/en/communication/news/focus-on-overview/ocean-biogeochemistry/].

75 Lufthansa, Lufthansa Innovation Hub startet Kompensationsplattform „Compensaid" und setzt auf $CO_2$-neutrale Flugkraftstoffe, [https://newsroom.lufthansagroup.com/german/newsroom/lufthansa-innovation-hub-startet-kompensationsplattform--compensaid--und-setzt-auf-co2-neutrale-flug/s/6021e78d-3d72-4eb7-aaaa-cc359724fae5].

this and SAF, determined by how fast the customer wants to offset their emissions. Offsetting costs vary considerably depending on the option chosen, with immediate offsetting being the more expensive option. If, for example, the emissions of a flight from Munich to Berlin are offset (approximately 80 kg $CO_2$ per passenger), immediate offsetting costs amount to EUR 39 (approximately EUR 500/t $CO_2$), while offsetting emissions over 20 years through reforestation results in costs of only EUR 1.60 (around EUR 20/t $CO_2$).

Since the start of the program in August 2019, over 82 million passenger kilometres have now been offset from almost 27,000 flights and 149 airlines. Some 35,000 trees have been planted for EUR 120,000, and 575,000 litres of SAF have been purchased for EUR 580,000.

### Negative emissions plant in Iceland[76]

In order to further promote the technological development of direct air carbon dioxide capture and storage, Climeworks offers to capture a specified amount of $CO_2$ from the air and store it geologically as rock for a monthly fee. The $CO_2$ is separated from the air using direct air capture, mixed with water, and pumped underground. Through natural processes, the $CO_2$ reacts with basaltic rock and, within a few years, is mineralised (as calcite). This prevents the $CO_2$ from escaping at a later date and ensures long-term storage in a sustainable manner. The $CO_2$ capture and storage costs amount to around EUR 1,000/t $CO_2$. The greatest geological potential for this form of $CO_2$ storage lies under the sea, where the 200 nautical miles around Iceland are estimated to be able to store up to 7,000 Gt $CO_2$. The greatest challenge with this form of storage is the high water requirements.[77]

### Northern Lights: new business areas with carbon capture and storage[78]

As part of the Northern Lights project, Equinor is working with Shell and Total to develop infrastructure that will enable the transport and storage of $CO_2$ on the Norwegian continental self.

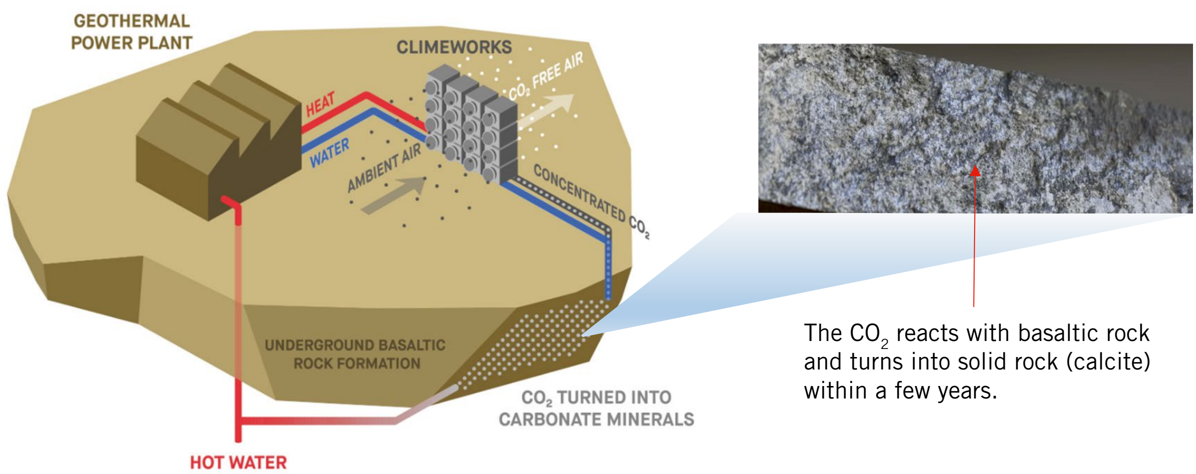
In the vicinity of Oslo, $CO_2$ emissions from waste incineration and industrial sources are captured and liquefied. The liquid $CO_2$ is transported by tankers, similar to LPG transport ships, to a terminal in the Naturgassparken industrial area in the west of the country. From there, the $CO_2$ is transported via a 110 km pipeline up to 3,000 metres below the seabed for long-term storage. The total potential storage capacity is estimated at around 100 Mt $CO_2$. Initially, the annual storage capacity of the project will be 1.5 Mt $CO_2$, which is the equivalent to the emis-

76 Climeworks, [https://climeworks.com].

77 Sandra Ó. Snæbjörnsdóttir et al, $CO_2$ storage potential of basaltic rocks offshore Iceland, Energy Procedia Vol. 86 (2016).

78 Northern Lights Project, [https://northernlightsccs.eu/en/about].

**Figure 1.33: Functioning of the Climeworks process and a picture of the stored carbon dioxide**

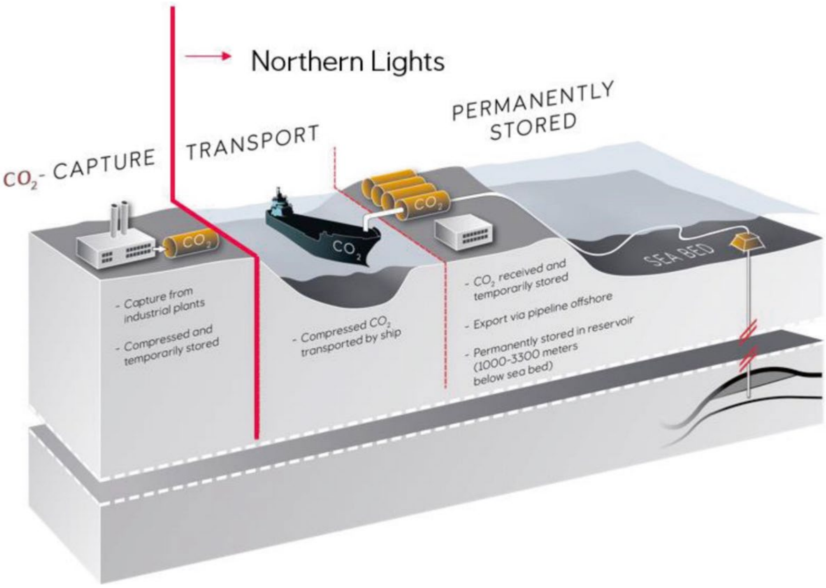



Source: Climeworks

sions of 135,000 people living in Germany.[79] If $CO_2$ emitters on continental Europe require further storage capacity, the capacity will be increased to 5 Mt $CO_2$ per year in a second phase. Subject to further investment by project partners and the Norwegian government, phase one is planned to commence operations at the end of 2023.

79 Assuming a $CO_2$ footprint of 11 t $CO_2$eq for an individual living in Germany.

**Figure 1.34: Overview of the Northern Lights concept for carbon capture, transport, and storage**




Source: Equinor, Northern Lights Project

## 1.6 Conclusion

Achieving climate neutrality or a negative emissions balance is a lengthy task that poses challenges for all parties: countries have to develop a decades-long strategy that is flexible enough to integrate new approaches and technologies as quickly as possible. Companies will have to change their production and processes in order to keep GHG emissions as low as possible and look for ways to achieve a negative emissions balance. Private households will need to adapt to higher costs for energy, housing, transport, and food. Climate neutrality cannot usually be achieved without effort or cost – counterexamples like Bhutan illustrate the constellation of advantages that is needed to accomplish this.

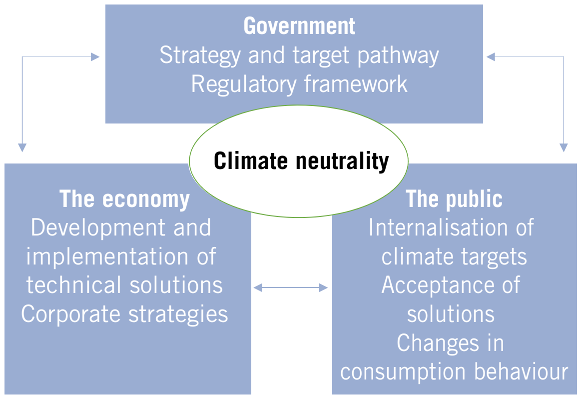
Achieving climate neutrality requires a policy framework that expedites investments as quickly as possible. Delays in the necessary investments will lead to higher costs and supply bottlenecks for the relevant technologies, as too much will then be invested in them over too short a time period.

Negative emissions technologies should not be seen as a substitute for emission reduction measures, but as a very important complement to these. In certain sectors and for GHGs other than $CO_2$, emission reduction services can often be provided only with great difficulty or at very high cost.

Climate neutrality is an ambitious task. As such, all available measures need to be considered: emission-free energy generation, CC(U)S for process emissions, energy efficiency, electrification, and the use of hydrogen to make the transport and heating/cooling sectors emission free in the private household sector as well. NET is a new measure that can be applied on top of these.

Social acceptance among the population groups that, for example, are opposed to the expansion of energy infrastructure, will not be sufficient on its own, as achieving a climate-neutral society requires the active participation and willingness to change of all parties and members of the public. Climate neutrality is a goal that entails very far-reaching changes in lifestyles as well as sacrificing a certain level of comfort, for example, through changes in consumer behaviour and land use. If politicians do not succeed in establishing climate neutrality as a deeply ingrained goal of society, these sacrifices will not be accepted by parts of society and the required measures to reduce emissions will not be able to be implemented. It is not enough to reach a general consensus on achieving climate neutrality, rather politicians have to succeed in communicating the changes in everyday life that this entails to the general public.

**Figure 1.35: Climate neutrality requires the participation of all stakeholders**




Source: World Energy Council

Crises like the coronavirus pandemic can be used on various levels to help achieve climate neutrality:

- at the level of the individual, with a shift to sustainable behaviours (e.g., through increased use of telecommunications to reduce the commute to work or business trips); and
- at the level of the state, if policy responses to the coronavirus pandemic result in increased cooperation between countries and not reflexive nationalism.

The initial reflex to the coronavirus pandemic was an emphasis on security of supply and on maintaining as much energy autarky as possible – but this may change in the aftermath of the crisis. Similarly, following the time-consuming phase of restarting business after the lockdown, companies will have to think again about strategic issues such as climate protection.

It remains to be seen to what extent funds will now flow into the health sector and thus no longer be available for climate protection. This should prove an incentive to devote more attention to the issue of economic efficiency in climate protection, so more climate protection can be achieved with lower levels of investment.

## WORLD ENERGY COUNCIL

Algeria
Argentina
Armenia
Austria
Bahrain
Belgium
Bolivia
Bosnia and Herzegovina
Botswana
Bulgaria
Cameroon
Chad
Chile
China
Colombia
Congo (Dem. Rep.)
Côte d'Ivoire
Croatia
Cyprus
Dominican Republic
Ecuador
Egypt (Arab Rep.)
Estonia
Eswatini (Kingdom of)
Ethiopia
Finland
France
Germany
Greece
Hong Kong, China
Hungary
Iceland
India
Indonesia
Iran (Islamic Rep.)
Ireland
Israel
Italy
Japan
Jordan
Kazakhstan
Kenya
Korea (Rep.)
Latvia
Lebanon
Libya
Lithuania
Malta
Mexico
Monaco
Mongolia
Morocco
Namibia
Nepal
Netherlands
New Zealand
Niger
Nigeria
Pakistan
Panama
Paraguay
Poland
Portugal
Romania
Russian Federation
Saudi Arabia
Senegal
Serbia
Singapore
Slovakia
Slovenia
South Africa
Spain
Sri Lanka
Sweden
Switzerland
Tanzania
Thailand
Trinidad and Tobago
Tunisia
Turkey
Ukraine
United Arab Emirates
Uruguay

**Weltenergierat – Deutschland e.V.**
**Gertraudenstraße 20 I 10178 Berlin**
**Germany**
**T (+49) 30 2061 6750**
**F (+49) 30 2028 2462**
**E info@weltenergierat.de**
**www.weltenergierat.de**
**WEC_Deutschland**