Pathways | Germany | All sectors

PATHWAY TO CLIMATE NEUTRAL GERMANY

KEY MESSAGE

Achieving **climate neutrality in Germany by 2045 is feasible, given:**

- an adequate legislative framework: we need to **prepare now** to achieve our 2030 targets and beyond;
- an **acceleration of the green transition** in the energy, heating/buildings, transport and industry sectors;
- a **massive and comprehensive investment programme,** which includes making good use of current recovery funds to move the economy towards climate neutrality.

Achieving climate neutrality by 2045 rather than 2050 **avoids** almost **one additional billion tonnes of CO_2 emissions.**

Besides achieving climate neutrality, industrial transformation will also **improve** people's **quality of life** by reducing noise and air pollution, as well as provide better quality of housing.

OVERVIEW

This pathway to climate neutrality by 2045 is optimised for cost and feasibility, with economically efficient measures fitting into existing investment cycles:

- renewables-based energy sector;
- Complete coal phase-out by 2030;
- mass electrification (heating, transport, industry);
- smart and efficient modernisation of buildings;
- development of the hydrogen economy for applications where direct electrification is not feasible;
- development and deployment of climate neutral technologies;
- phase-out of fossil fuels in the energy, buildings, transport and industry sectors by 2045; and
- carbon capture and storage for residual emissions (cement and lime industries; agriculture).

By 2030, this includes:

- a 70 percent share of renewables in electricity generation;
- 6 million heat pumps and an increase in the buildings green retrofit rate of at least 50 percent (14 million heat pumps by 2045);
- 14 million electric cars on the road; and
- the use of some 60 TWh of clean hydrogen.

This pathway essentially **modernises the energy sector, transport system, buildings and industrial plants** through public and private investments.
It assumes an average economic growth of 1.3 percent per year throughout 2045. Compared with the 2050 scenario, additional emission reduction will be possible in the industry and energy sector (up to 77 million tonnes of CO_2 equivalent), and to a smaller extent in the transport and building sectors (5 million tonnes in each).

This pathway would provide tangible co-benefits by improving quality of life in several ways:

- less noise;
- less air pollution;
- reallocation of urban space in densely built areas thanks to the decreased need for parking space;
- buildings warm in winter and cooler in summer, due to improved insulation thanks to retrofits (as summers get hotter due to climate change); and
- the expansion of organic farming means a higher likelihood of safeguarding biodiversity and its services for agriculture and recreational activities.

This pathway is **less costly and damaging than non-action scenarios,** where climate change is not mitigated.

AIMS & TARGETS

Climate neutrality can be achieved in 3 steps:

→ 65 percent reduction in greenhouse gas (GHG) emissions by 2030 via the replacement of traditional fossil-based technologies (instead of current –55 percent target)
→ Complete transition to climate-neutral technologies, for a total emission reduction of 95 percent by 2043 and climate neutrality by 2045.
→ Offset residual emissions (estimated at 5 percent compared with 1990 levels in 2045) in industry, agriculture and waste sectors

Climate neutrality rests on 3 pillars:

→ Energy efficiency and the reduction of energy demand
→ Renewable electricity generation and mass electrification
→ Hydrogen as an energy source and raw material

By 2030, a 65 percent GHG emission reduction relative to 1990 levels:

Reduce traditional technologies' market share (internal combustion vehicles, fossil-fuel heating systems, natural gas-based chemical plants) and phase them out by 2030. The decarbonisation of the energy sector represents almost half of the reduction in emissions needed, followed by the transport sector with electrification and an increase in modal and soft transport use, the industry sector, and the building sector, with green and smart retrofits, including heat pump deployment and the expansion of district heating.

→ Energy
- Coal phase-out
- 70 percent of renewable energy in electricity generation (offshore and onshore wind, photovoltaics (PV))
- Incremental use of hydrogen for backing up renewables in power stations and combined heat and power (CHP) plants from late 2020s onwards
- Decarbonisation and expansion of district heating
- Smart grids, smart metering, smart appliances, demand response, prosumers, aggregated demand response for consumers

→ Transport
- Electric vehicles deployment:
  - 80 percent of new car sold electric or plug-in hybrids
  - 30 percent of road freight kms electric (electric trucks powered by batteries, overheads lines and fuel cells)
  - Plug-in infrastructure development
- Increase in rail use, including for goods transportation
- Increase in public transport
- Soft transport (walking, cycling etc.) infrastructure deployed
- No new passenger cars with combustion engines to be registered after 2032: all new passenger cars to be zero emission cars

→ Industry
- Deploy climate-neutral technologies for the 50 percent of basic materials plants in need of refurbishment up to 2030
- Introduce Direct Reduced Iron (DRI) process
- Deploy hydrogen for steam
- Deploy/retrofit infrastructure for industrial hydrogen use and carbon, capture and storage (CCS) systems
- Phase out coal
- Develop recycling and use of secondary raw materials (initiate circular economy)

→ Buildings
- Retrofit rate at 1.75 percent a year
- Heat pumps for heating and cooling
- Increase district heating access
- Use of renewable energy sources

→ Agriculture
- Expansion of organic farming

- Fertiliser use reduction
- Livestock reduction
- Switch to crops with lower nitrogen requirements
- Fermentation and improved storage of farm manure
- Low-emission manure spreaders

→ Waste
- Reduction in methane emissions from landfills due to further reduction in deposited organic waste amount between 1990 and 2018
- Further reduction of methane emissions by expanding landfill ventilation measures

By 2045, net-zero GHG emission reduction relative to 1990 levels:

Continue electrification across all sectors; importance of hydrogen grows, both as energy carrier and raw material; biomass's role increases, in use when no good alternatives are available and carbon capture and storage (CCS) is suitable, such as in the chemical and steel industries.

→ Energy
- Continued expansion of renewable energy sources (mostly wind and solar PV), to meet increasing electricity consumption due to mass electrification and hydrogen production
- 2040: Hydrogen beats out natural gas for residual electricity generation
- 2045: Zero-carbon electricity and district heating

→ Industry
- Continue to use more electricity, hydrogen and biomass, becoming largely climate neutral by 2045
- Climate-neutral technologies in use for all basic materials plants
- CO_2 grid completed by 2045
- Raw materials for chemicals replaced by recycled products and synthetic feedstocks based on non-fossil CO_2, starting in 2030
- Cement industry uses CCS to capture residual emissions

→ Building
- Pursue green retrofits and new energy-efficient buildings; covers 90 percent of building stock by 2050
- Complete shift to climate-neutral heat production; focus on heat pumps and district heating networks

→ Transport
- Develop carpooling and public transport use
- EVs (batteries powered)
- Trucks powered by batteries, overhead lines and fuel cells
- Increase in share of goods transported via rail
- Air transport and shipping powered by electricity-based synthetic fuels
- 2045: National fleets almost only consisting of EVs
- 2045: Road freight, buses and rail will almost be entirely electrified

→ Agriculture
- Further livestock reduction
- Fermentation of large quantities of manure in biogas plants
- Change in agricultural soils management to reduce nitrogen input:
  - increase nitrogen efficiency by optimized use of manure
  - expand organic farming (less nitrogen input per hectare as no synthetic fertilizer used)
  - expand ecological priority areas (areas without nitrogen input)
  - expand legume cultivation
  - pursue the switch to crops with lower nitrogen requirements
- Reclaim drained wetland soils as wetland, so as to reduce GHG emissions from organic soils. Such areas may be further used for adapted agricultural production such as paludiculture (e.g. growing reed for energy purposes or material uses)
- Plant-based and synthetic milk and meat alternatives estimated to make up 15 percent of market share

→ Waste
- Further reduction in emissions from landfills
- Further reduction in emissions from the biological treatment of organic waste
- Further reduction in emissions from wastewater treatment

→ Dispose of residual gas emissions in the industry, agriculture and waste sectors via:
- Biomass CCS (BECCS)
- Direct air carbon capture and storage (DACCS; more costly than BECCS)
- Green polymers CO_2 absorption (green naphtha)

The pathway is anchored on 3 pillars:

→ **Energy efficiency and the reduction of energy demand** (all energy sources used in Germany directly or for conversion to secondary energy sources) will half primary energy consumption by 2045, especially by
- lowering losses from energy conversion (wind and PV have no conversion losses); and
- decreasing final energy consumption (energy efficient buildings, lighting, electric devices, electric transportation, heat pumps)

→ **Mass electrification** and the green production of hydrogen will significantly increase final electricity consumption by some 60 percent compared with today.
- Electricity consumption will increase in transport, hydrogen production and industry
- Electricity consumption will decline slightly in the building sector
- Renewables installed capacity will increase greatly, from 117GW in 2018 to 268GW in 2030 and 608GW in 2045, or a 5-fold increase
- Spatial and temporal distribution of power generation will contribute to balancing variable renewables generation
- Flexible electricity system, with battery storage, heat pumps, electrolysers, electric cars and electricity trading across borders

→ **Hydrogen,** both locally produced and imported, will be used both as an **energy source and a raw material,** as well as other synthetic fuels and feedstocks
- Hydrogen demand is estimated at 265 TWh by 2045, with 36 percent produced in Germany
  - Industry will use clean hydrogen for no-regret applications, such as the production of CO_2-free steel with the direct reduction of iron ore (DRI) and electric arc furnace (EAF) route
  - Transport will use an estimated 40TWh (freight)
  - Electricity generation will use most of the hydrogen for residual demand
- In addition, 160TWh of CO_2-neutral Power-to-liquid (PtL) fuels and green naphtha will be imported:
  - CO_2-neutral Power-to-Liquid for shipping and air transport will be used
  - Green naphtha for industrial materials not provided by recycling
- Demand of hydrogen and other synthetic fuels and feedstocks totaling 422TWh, of which 326TWh imported by 2045

POLICY INSTRUMENTS

With a European GHG emission reduction target of 55 percent by 2030, the German **'2019 Climate Protection Act'**, needs to be **revised for climate neutrality by 2045.** Additional GHG emission reductions are needed, with the biggest potentials for reductions in the energy and industry sectors respectively.

The following needs to be envisaged:

→ The combination of market-based incentives, targeted support mechanisms and regulatory policies; and
→ reforms of the energy taxes, levies and duties to foster energy efficiency measures, renewable energy and phase out fossil fuels.

Energy

→ Coal phase-out market-driven via EU ETS' carbon pricing; projected CO_2 price at ca. €50/tonne makes lignite-fired power plants uneconomical

Industry

→ Upstream
- Hydrogen investment support policy framework (i.e. through a hydrogen contract for difference)
- Industrial energy and CO_2 infrastructure planning and financing
- EU level: Robust clean-hydrogen sustainability criteria

→ Midstream
- Carbon contract for difference (CCfD)
- Capital derisking instruments for unproven technologies
- EU level: Climate-neutral production standards and reformed anti-carbon leakage system

→ Downstream
- Climate surcharge on CO_2-intensive final products
- Requirements and labels for embedded CO_2 in intermediate and final products
- Recyclable product standards, recycling quality targets and end-of-life obligations
- Green public procurement requirements

Transport

→ EU further tightening CO_2 limits for passenger vehicles
→ EV deployment policy
→ Electricity market design

Multiple comprehensive strategies needed:

→ Comprehensive strategy for biomass (inclusive of agriculture, nature conservation and climate neutrality)
→ Comprehensive strategy for hydrogen (needs, domestic and imported capacity, transport, timing)
→ Carbon capture and storage strategy (needs, transport routes, sites, timing)

Sources

Prognos, Öko-Institut, Wuppertal Institut (2021):
Towards a climate-neutral Germany by 2045. How Germany can reach its climate targets before 2050. Executive Summary conducted for Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende.
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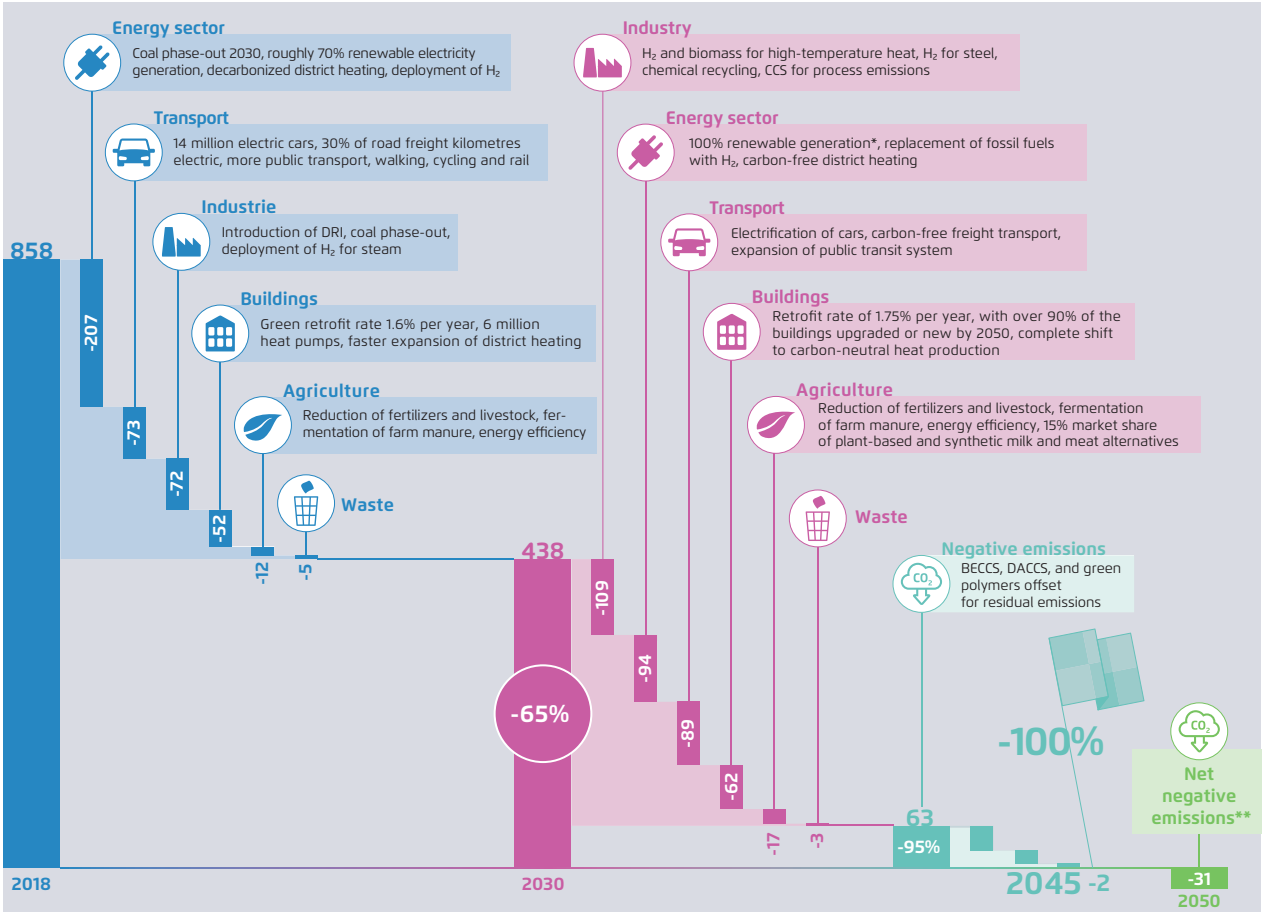
Dual benefit stimulus for Germany – A proposal for a targeted 100 billion euro growth and investment initiative
Retrieved from https://www.agora-energiewende.de/en/publications/dual-benefit-stimulus-for-germany/

Measures for the climate-neutral 2045 scenario (CN2045)
(Greenhouse gas emissions in Mt CO_2e)

Figure 1

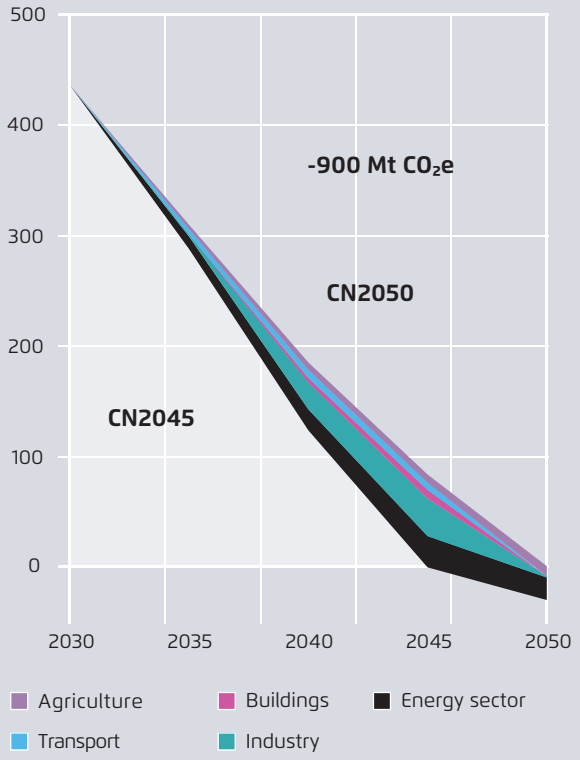


H_2 = Hydrogen
* This includes electricity generated from renewably generated hydrogen,
** This figure merely extrapolates the trend after 2045; further emissions reductions are possible.

Prognos, Öko-Institut, Wuppertal Institut (2021): Towards a climate-neutral Germany by 2045. How Germany can reach its climate targets before 2050. Executive Summary conducted for Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende.

Additional GHG savings and measures by sector — Figure 2

Additional reductions of GHG emissions between the CN2050 and CN2045 scenarios in Mt CO_2e



Measures for reaching climate-neutrality by 2045

-104 Mt

- Reduced livestock due to higher demand for milk and meat substitutes
- Accelerate expansion of organic farming to 25% of farms
- Expansion of peatland rewetting and increase of biodiversity areas

-73 Mt

- No permitting of new combustion engine cars or plug-ins from 2032 onwards
- Fleet of cars and trucks in 2045 almost completely free of combustion engines
- PtX for inland waterway transport already from 2031

-68 Mt

- Accelerate expansion of heat pumps and district heating networks
- Replace all fossil heating technologies by 2045
- Increase building retrofit rate to 1.75%

-308 Mt

- Accelerate expansion of CCS infrastructure
- Accelerate availability of biomass for BECCS
- Accelerate shift of energy source to electricity and hydrogen

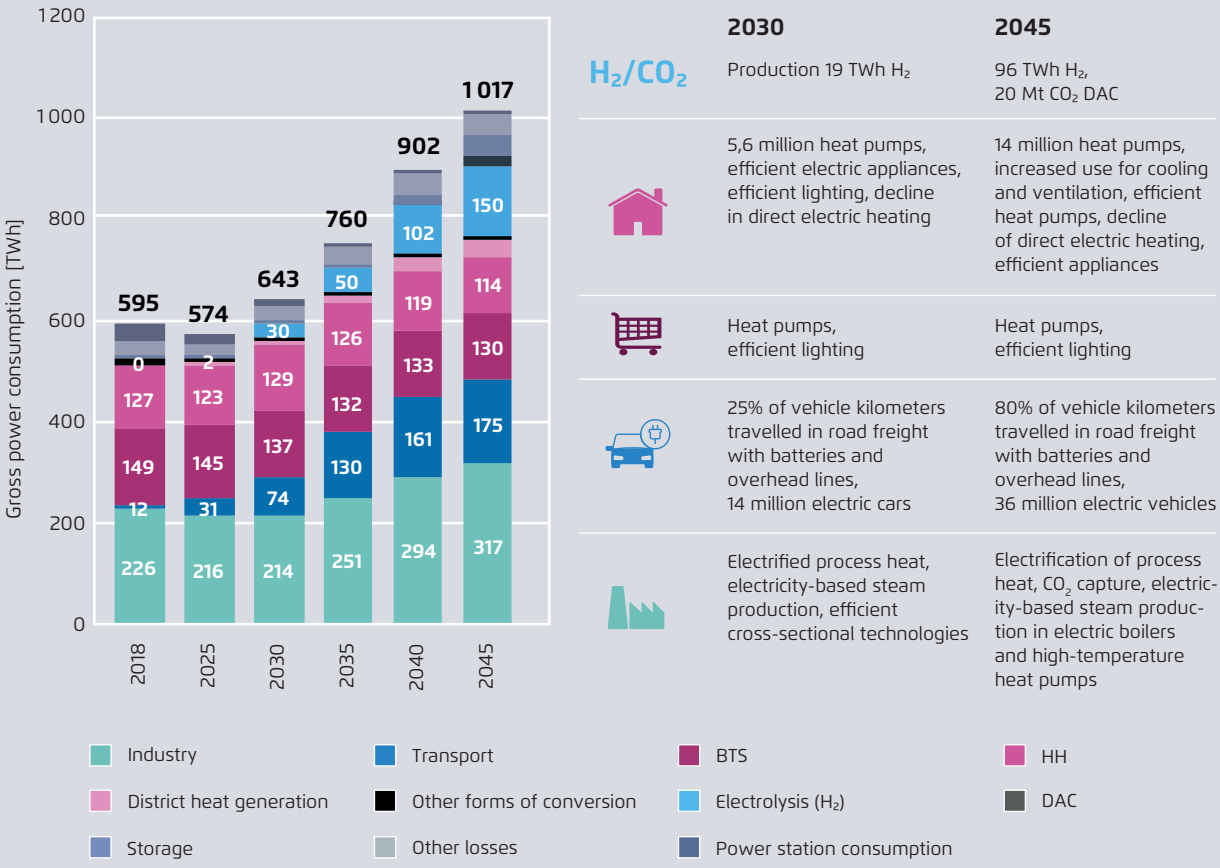
-345 Mt

- Accelerate and increase renewable expansion starting in 2030
- Increase negative emissions through DACCS
- Accelerate replacement of natural gas with hydrogen
- Increase inland hydrogen production

Prognos, Öko-Institut, Wuppertal Institut (2021): Towards a climate-neutral Germany by 2045. How Germany can reach its climate targets before 2050. Executive Summary conducted for Stiftung Klimaneutralität, Agora Energiewende and Agora Verkehrswende.

Gross power consumption

Figure 3



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DAC = Direct Air Capture, HH = Households, BTS = Business, trade and services.
Storage demand includes pumped storage hydro and stationary battery storage in public grids.
Power consumption of home batteries in combination with PV systems is not considered here.

Learn more:
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