



MEMO • Published May 27, 2022

COUNTRY SUMMARY: GERMANY

ANALYSIS OF NET-ZERO PATHWAYS FOR THE EU AND UK

OVERVIEW OF MODELLING ANALYSIS

Carbon-Free Europe (CFE) modeled five potential pathways for the EU and UK to achieve net-zero emissions by 2050. The **Core** pathway is the least constrained, allowing countries to use all available clean energy technologies and assuming high levels of energy efficiency and electrification. This is the most feasible, cost-effective pathway to net-zero. The other four pathways are designed to explore how different policy and implementation constraints impact the route to carbon-neutrality. To learn more about the other pathways and our full analysis, visit www.carbonfreeeurope.org.

TODAY'S ENERGY SYSTEM

In 2019, 77% of Germany's energy supply came from fossil fuels (18% from coal, 25% from gas, and 34% from oil). Nuclear energy supplied 7% and renewable energy sources, including biomass, provided 15%. 32% of Germany's emissions in 2019 came from the energy sector (primarily electricity generation), 31% from industry, 20% from transport, and 16% from residential and commercial buildings. 2019 is a good baseline year to understand Europe's long-term energy demand and supply since impacts from the pandemic have heavily skewed data from 2020-2021. 2019 is also the most recent year for which Eurostat data is available.

KEY TAKEAWAYS: THE CORE PATHWAY IN 2050

- 1. Germany's most feasible and cost-effective pathway to net-zero is the Core pathway, which includes the use of carbon capture and every available clean energy technology except for nuclear power.** In this pathway, by 2050, Germany's estimated electricity mix is 34% wind, 32% solar, 20% geothermal, and 10% gas. The Core pathway requires 256 billion Euros of investment in zero-carbon electricity generation sources through 2050. Our modelling excludes nuclear power from Germany's future domestic energy supply based on the country's current nuclear energy policy.
- 2. By 2050 in the Core pathway, Germany adds 214 GW of renewable electricity capacity.** This includes 148 GW of solar photovoltaic energy, the 3rd most of any EU + UK country; 17 GW of offshore wind and 25 GW of onshore wind through 2050, the 7th and 8th most (respectively); and 24 GW of geothermal energy. Germany is the only EU + UK country to add more than 1 GW of geothermal capacity in the Core scenario.

3. **Germany adds up to 53 GW of battery storage, the most of any EU + UK country. Germany adds at least 40 GW of battery storage in all scenarios except when nuclear power is entirely phased out across Europe (in the 100% Renewables pathway).** Under the constraints of the 100% Renewables pathway, Germany has less access to electricity imports and builds more geothermal, reducing demand for energy storage to 24 GW. This happens despite the rest of Europe adding 50% more battery storage capacity compared to the Core scenario.
4. **Germany is a significant importer of electricity in 2050, building 63 GW of new electricity transmission by 2050.** This transmission addition is the largest of any EU + UK country and more than triples existing import/export lines.
5. **Germany's decarbonised economy consumes large quantities of hydrogen, most of which is imported via new pipelines.** Germany builds 23 GW of new hydrogen pipelines by 2050, the 6th most among EU + UK countries. Germany produces 5 kilotonnes of hydrogen annually by 2050, the 27th most among EU + UK countries. All hydrogen produced domestically uses low-temperature electrolysis, as zero-carbon high-temperature electrolysis requires nuclear heat.
6. **By 2050, Germany sees the largest reduction in end-use gas and oil demand of any EU + UK country**¹. This large reduction in demand is driven primarily by Germany's high oil and gas demand in 2019.
7. **In the Core pathway, Germany is a large producer of biofuels and e-fuels, producing nearly 14,000 and over 2,000 kilotons of oil equivalent (ktoe), respectively.** Germany is the 2nd largest producer of biofuels and the 8th largest producer of e-fuels.
8. **By 2050, Germany sequesters 59 million tons of CO₂ annually in geologic formations. This is the most geologic sequestration of any EU + UK country.** The sequestered CO₂ is captured from production of biofuels and cement.
9. **Germany's high historical pace of renewables deployment will need to be sustained through 2050 to reach net-zero.** From 2011 to 2020, Germany built on average 7 gigawatts of renewable energy per year. To meet demand, Germany will need to continue to build between 5 and 7 gigawatts annually through 2050.

KEY ENERGY METRICS

The table below shows key energy system metrics from the **Core** pathway, which is the most cost-effective, feasible trajectory to net-zero. The table also shows a range for each metric. That range is generated by comparing the **Core** pathway to four other modelled pathways designed to evaluate specific constraints.

The **Slow Demand Transformation** pathway imposes delays in electrification of surface transportation, heating, and industry. The **100% Renewables** pathway relies strictly on renewables, phases out nuclear power, and prevents carbon capture and sequestration. The **Limited Renewable Siting** pathway restricts the deployment of wind and solar to reflect land-use and siting constraints. The **Domestic Preference** pathway prioritises domestic energy supplies and reduces transborder transmission lines and pipelines.

We provide a range for each metric in the table to indicate which model results are highly sensitive to constraints, and which are consistent across all scenarios such that they represent low-regret strategies. We also show Germany's rank in each metric relative to all EU + UK countries, to identify segments of the decarbonised energy economy where Germany has an opportunity to lead.

Category	Metric	Core Case	Min	Max	EU & UK Rank
Demand Transformation	electrification share (% of final demand)	50%	44%	50%	13
	reduction in end-use gas demand (ktoe)	-34,148	-25,574	-34,148	1
	reduction in end-use oil demand (ktoe)	-74,693	-67,042	-74,693	1
	zero-emission vehicles (million vehicles)	57	55	57	1
Electricity	new battery storage (GW)	52	24	53	1
	new solar (GW)	148	100	148	3
	new offshore wind (GW)	17	17	17	7
	new onshore Wind (GW)	25	9	25	8
	new geothermal (GW)	24	20	44	1
Fuels	biofuels (ktoe)	13,884	9,404	14,169	2
	e-fuels (ktoe)	2,169	587	7,807	8
Hydrogen	electrolysis - low temperature (kilotonnes h2)	5	5	14	27
Other Resources	Biomass (million dry tons)	70	51	71	2
	geologic sequestration (million tons co2)	59	46	60	1
Transmission and Pipelines	new electricity transmission (GW)	63	22	63	1
	new h2 pipelines (GW)	23	18	91	6

Table 1: <https://www.carbonfreeeurope.org/modeling>

ENDNOTES

1. This takeaway is a 2050 projection based on 2019 historical data. It does not reflect recent prioritisation of gas phase-out for geopolitical reasons, which we do not expect to be a strong predictor of residual gas demand in 2050. All countries in our analysis significantly reduce gas consumption by 2050.